

Phoenix Program



Translated by Ádám Vécsey
Phoenix logo designed by Krustovin August
Explanatory illustrations by Roland Gadár

2022

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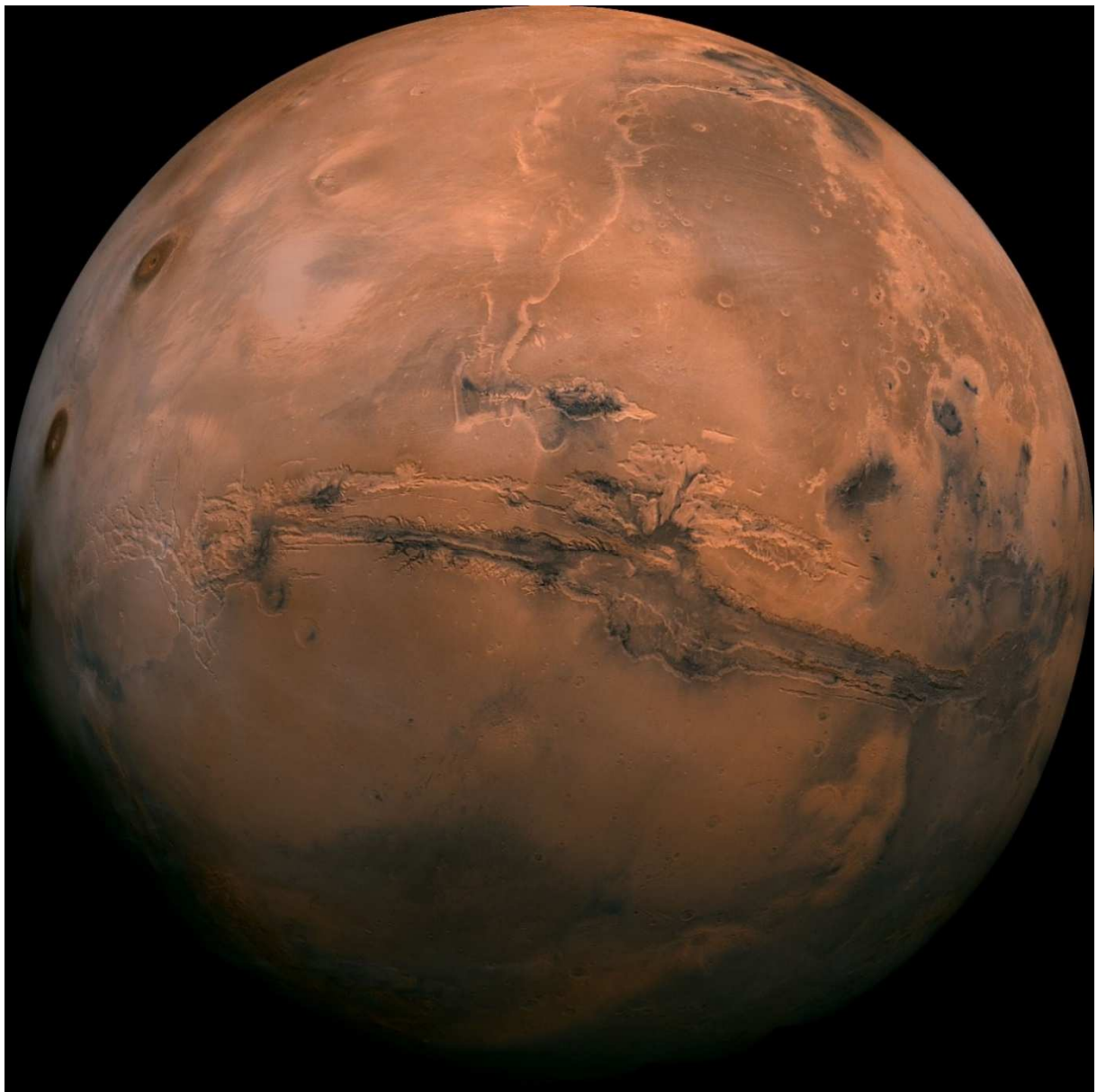
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Introduction: Our Journey to Mars

Human history is the chronicle of individualism where the countless successes and failures of famous and infamous people forged the new generations' knowledge on the past and their faith in the future. Avenues, bridges and schools are named after the distinguished people to be remembered forever, however, as wars cannot succeed without self-sacrificing soldiers, scientific results cannot succeed without a supporting community either. Conquering Mars demands the most prominent minds of humankind to face fear and solitude on a very long and dangerous mission, as well as ordinary people to give up on a specific portion of resources devoted to community development at the same time. This document aims to introduce the resulting opportunities.

Balázs Sashalmi



1. Valles Marineris canyon on the surface of Mars (Credit: NASA)

Chapter 1: Aerial Launch Vehicle System

Surface launches sending a payload at least to low Earth orbit are extremely expensive, not only on account of the manufacturing costs of the launch vehicles, but also because excessive infrastructure is required to use launch complexes, which allows only a limited number of not accurately plannable annual launches due to slow and circumstantial preparations and weather-dependent launch windows.

Cost-efficiency is of utmost importance for the practicability of deep space missions. Relying on the existing launch vehicles and space port infrastructures, we could indeed plan a virtually endlessly complex manned deep space program, however, raising hundreds of millions of dollars required to funding such missions is hopeless.

A huge technological leap compared to surface launches was “Roc” by aerospace company Stratolaunch, which is a twin-fuselage mothership capable of launching hypersonic aircrafts and launch vehicles from above 10 kilometres by exploiting the smaller friction of a thinner atmosphere, however, this mothership’s humble carrying capacity of only 226 tonnes makes it unsuitable for application in deep space programs.

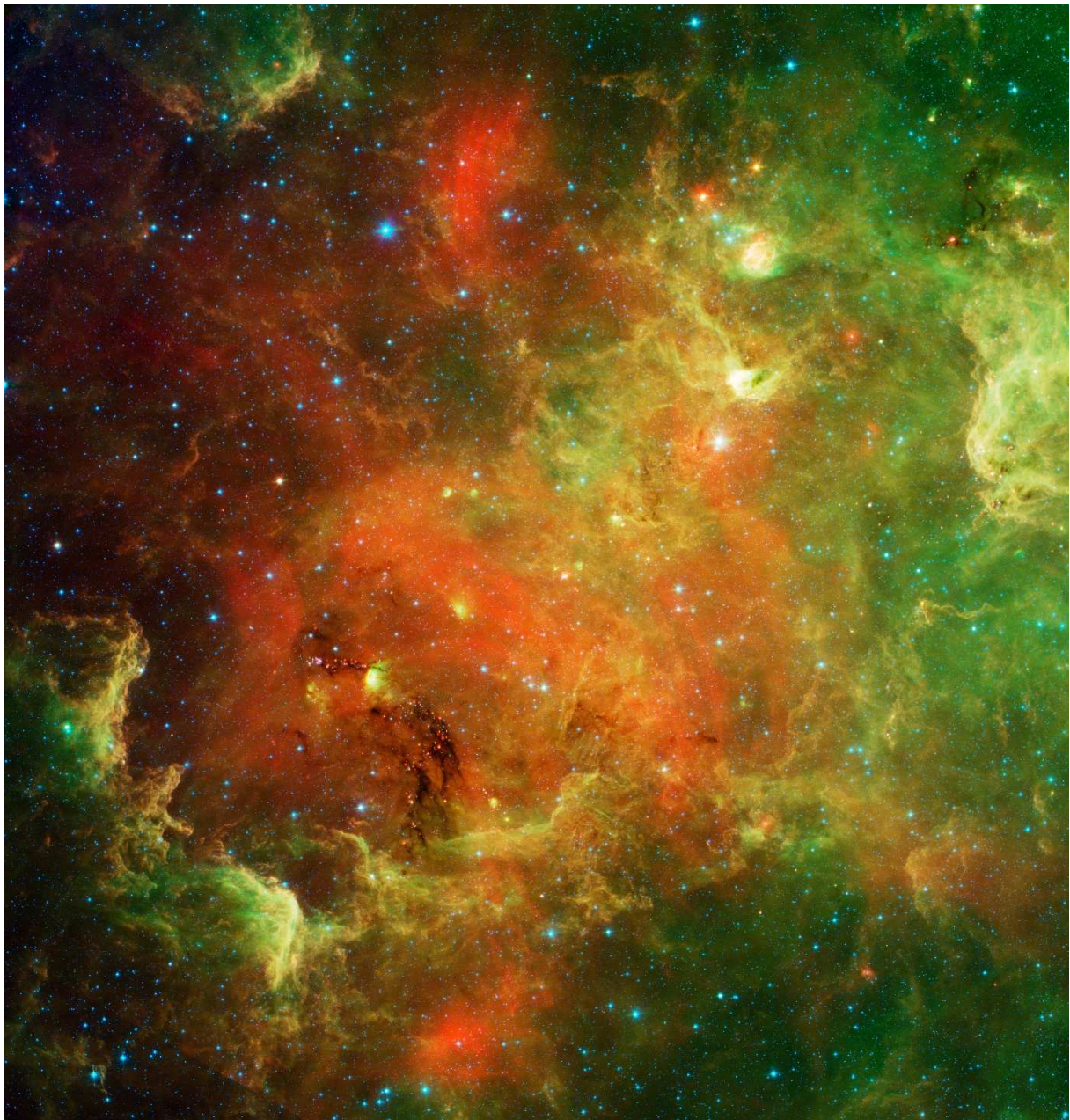


2. Stratolaunch mothership (Credit: Stratolaunch Systems)

The Stratolaunch mothership should at least have the double of its current carrying capacity so that it could send a payload at least to low Earth orbit as a suitable aerial launch vehicle system. This, however, is unfeasible by simply building a larger mothership, since Stratolaunch Roc is already the largest aircraft in the world with its wingspan of 117 metres.

Progress should therefore be achieved by other means, and instead of a larger traditional aircraft, a hybrid aircraft would be designed within the framework of Phoenix Program. This hybrid aircraft would also be a twin-fuselage aircraft similar to the Stratolaunch mothership, but instead of jet engines, it would fly with propellers actuated by electric motors.

Maximum launch altitude and speed would indeed be substantially lower with such propellers than what is achievable with jet engines, however, this solution would make a carrying capacity of 550 tonnes attainable, as the application of electric motors with a smaller weight, greater efficiency and better safety make it possible for the mothership to receive the large amount of energy required by the motors from an external source, i.e. from another aircraft, thus extricating itself from the weight of its own power generator and of the required fuel.



3. North America Nebula (Credit: NASA)

Consequently, this newly designed hybrid mothership could also be considered as a propeller-driven sailplane with a tow plane flying in front of it right from the take-off, where the mothership would be supplied constantly with the energy required for flying by the tow plane through two parallel high-voltage electric cables.

Since the launch vehicle takes off in horizontal position, which is unsuitable for aerial launch at an altitude of around 10 kilometres to reach space, the launch vehicle needs manoeuvring rocket engines or wings to set itself into vertical position directly after the launch. Since manoeuvring rocket engines would consume a great deal of rocket fuel to set the launch vehicle of several hundreds of tonnes into vertical position, wings would be the more weight efficient solution, which do not have to be fixed to the first stage of the launch vehicle, i.e. to the booster rocket, because if a reusable spaceplane serves as the second stage of the launch vehicle, that could carry out the necessary manoeuvres with its own wings.



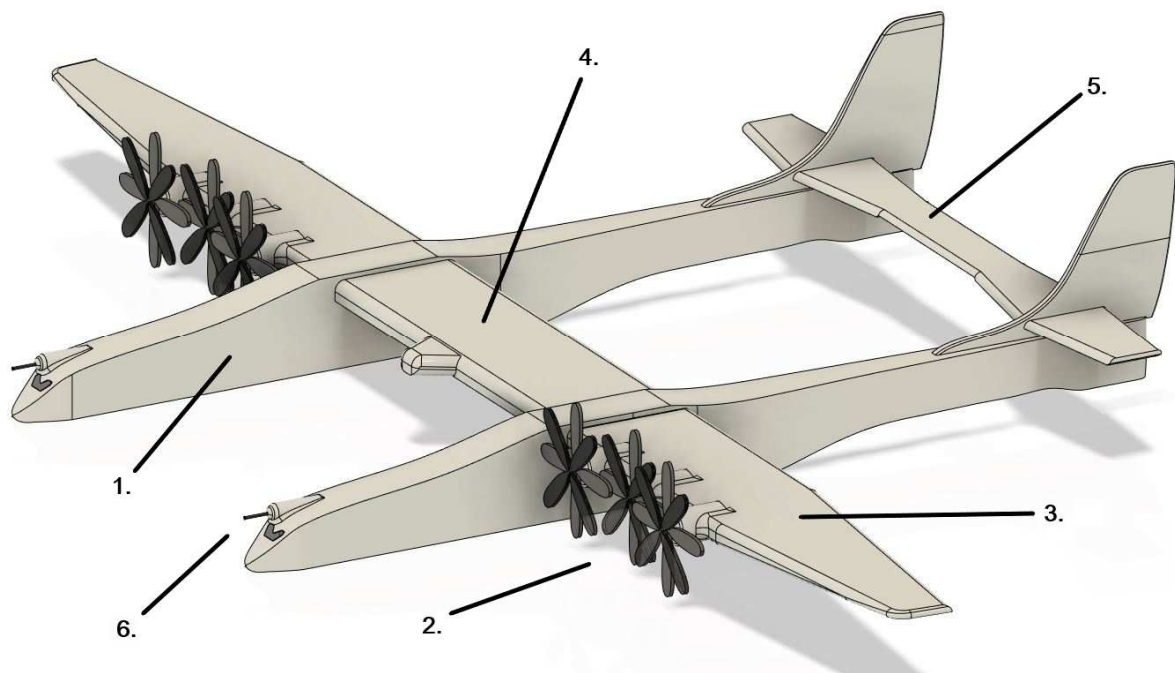
4. SpaceX Falcon 9 (Credit: SpaceX)

The first stage of SpaceX Falcon 9 v1.2 launch vehicle using RP-1 kerosene and liquid oxygen would be redesigned and made capable of aerial refuelling, and would launch as the booster rocket for Phoenix Program. This would allow launch vehicles launched from the mothership to be completely reusable in all cases, which is crucial not only by reason of the costs of each launch, but also because this allows us to carry out launches on any day of the year, regardless of the weather. For this, we only need to manufacture a sufficient number of reusable booster rockets and spaceplanes that would close the gaps of the examination and maintenance periods between the launches.



5. Black Eye Galaxy (Credit: ESA)

1.1 Structure of the Mothership



6. Mothership (simplified illustration; not to scale) (Designed by with additional ideas: Roland Gadár)

1. Twin-fuselage of the mothership. The retractable landing gear would be in the two parallel fuselages similarly to Stratolaunch Roc. Since the mothership would not have kerosene fuel tanks, large cryogenic tanks would be installed in their place in the fuselages. One liquid oxygen and one liquid hydrogen tank would be installed in each fuselage. These large cryogenic tanks would be provided with sufficient thermal insulation to prevent the evaporation of cryogenic rocket fuel over a longer period.

2. Coaxial propellers. The propellers would be fixed coaxially to the electric motors installed in the wings, so that the power output required for flying with an aircraft of such a humongous total weight can be achieved with propellers.

3. Increased wing surface area. While the absence of jet engines and kerosene tanks significantly decrease the structural weight of the mothership and more than 100 tonnes can be saved by excluding unnecessary kerosene, the omission of these will not double the carrying capacity as desired yet, since the electric motors used instead of the jet engines and the cryogenic tanks installed in the fuselages are extra weight. Thus, the mothership of Phoenix Program should have a significantly larger airframe than Stratolaunch Roc to achieve the desired carrying capacity of 550 tonnes.

4. Anterior load-carrying connector wing section. In contrast to the Stratolaunch mothership, this section is not only for fixing the launch vehicle during the flight and releasing it upon launch, but also for refuelling the reusable spaceplane serving as the second stage on the nose of the Falcon 9 booster rocket with cryogenic rocket fuel before launch. For this purpose, a refuelling- and fixing piece would extend forward in the middle of the wing section, connecting to the spaceplane between its two tilted, vertical stabilisers. This protruding piece is required because the booster rocket would be placed directly under the load-carrying connector wing sections, and the spaceplane

fixed to the nose of the booster rocket could only fit under the anterior load-carrying connector wing section due to its vertical stabilisers which extend upwards.

5. Posterior load-carrying connector wing section. The twin-fuselage of the mothership of Phoenix Program would be connected at another spot due to the significantly larger airframe and take-off weight. This posterior load-carrying connector wing section would also refuel the booster rocket with liquid oxygen from the cryogenic tanks installed in the fuselages of the mothership before the launch.

6. High-voltage electric cable connections. The noses of both fuselages of the mothership would be provided with a connecting point for the two high-voltage electric cables released parallelly by the tow plane. This is practically the electric version of the aerial refuelling system of flexible hoses. Both high-voltage electric cables would be capable of supplying the mothership alone, but since the tow plane and the mothership would be connected on the runway before the take-off, the two high-voltage electric cables could be used simultaneously to decrease the risk of accidental disconnection during flight.



7. Planned docking of American and Soviet spacecrafts (Artist's Concept) (Credit: Robert McCall)

1.2 Reusable Spaceplanes

The reusable spaceplanes serving as the second stage of the launch vehicle of Phoenix Program would be the smaller but more advanced versions of Space Shuttle Orbiter, reviving the former Orbital Space Plane Program (OSP) of NASA. The spaceplanes would be designed in three different versions, explicitly for reaching low Earth orbit, primarily the International Space Station (ISS) orbiting at an altitude of approximately 400 kilometres.

The main propulsion system of these spaceplanes would be a pressure-fed, vacuum-optimised rocket engine fuelled by liquid hydrogen and liquid oxygen. The storage capacity of the cryogenic tanks installed in the spaceplanes would be sufficient to reach at least low Earth orbit, manoeuvring in accordance with the purposes of the given mission, and then descending back into the atmosphere. Once descended back in the atmosphere, the spaceplanes, similarly to Space Shuttle Orbiter, would slow down by performing aerodynamic braking, gliding to the designated runway on a glide slope.



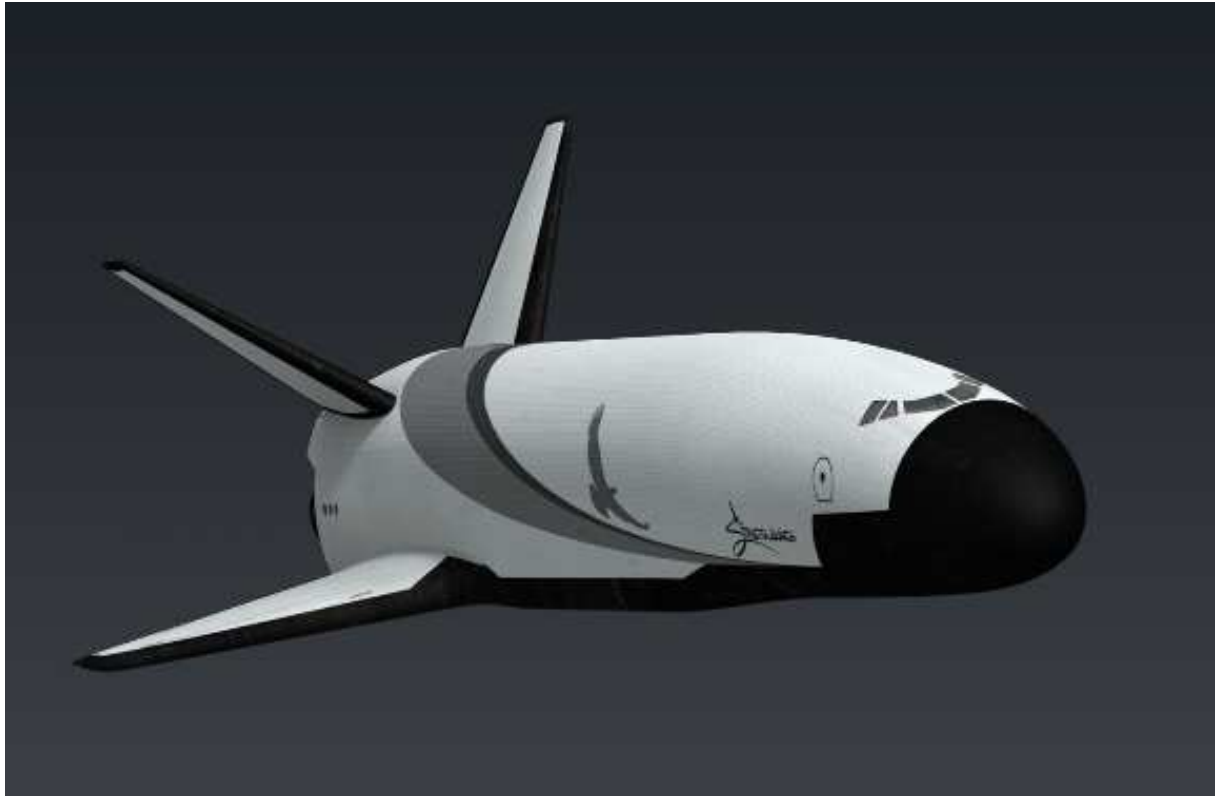
8. Atlantis Orbiter (Credit: NASA)

The three spaceplane versions of Phoenix Program: the unmanned cargo carrier version would be capable of orbiting payload, e.g. different sizes of satellites; another unmanned and remotely controlled propellant carrier version would bring LOX/LH₂ rocket fuel supplies continuously to low Earth orbit; and finally, the passenger carrier version would be for replacing the crew of the International Space Station.



9. Launch of Space Shuttle Atlantis (Credit: NASA)

The fuselage of the cargo carrier version would be provided with a cylindrical cargo hold in front of the cryogenic rocket fuel tanks. The doors of the cargo hold would open remotely, allowing the orbiting satellites and smaller CubeSats to leave the cargo hold. This spaceplane version would not be provided with a docking port, so when supplies are delivered to the International Space Station, the spaceplane would be captured and fixed by the Space Station's Canadarm2 robotic arm until the astronauts unload the cargo on a spacewalk.

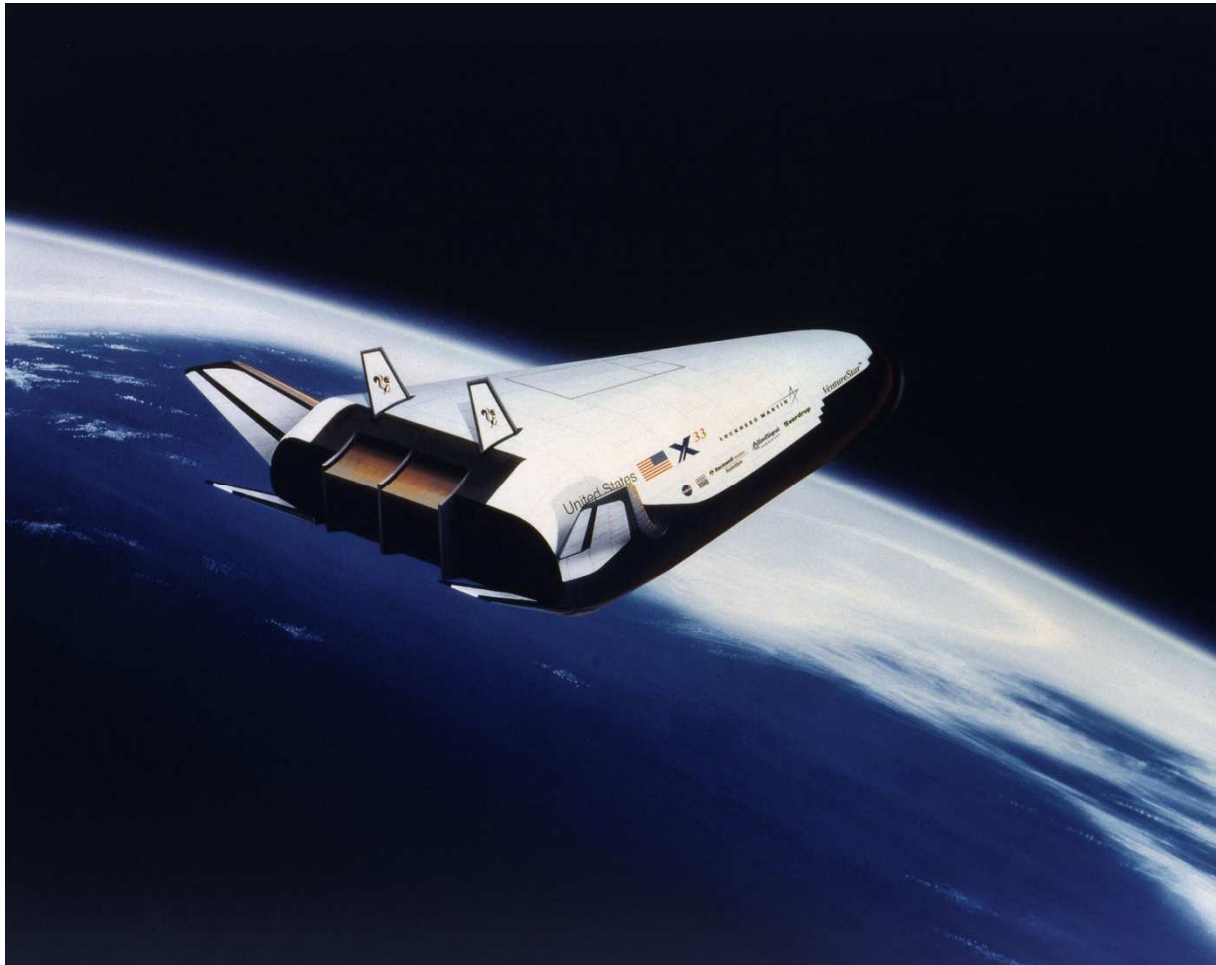


10. Stratolaunch Black Ice spaceplane (Artist's Concept) (Credit: Stratolaunch Systems)

Unlike Space Shuttle Orbiter, the passenger carrier spaceplane of Phoenix Program would not have a cargo hold for payload, making it unfit for orbiting satellites and other payloads. At the same time, however, the passenger carrier's liquid hydrogen and liquid oxygen tanks would have bigger storage capacities than those of the cargo carrier, and would also be equipped with a Canadarm robotic arm similarly to Space Shuttle Orbiter, allowing this spaceplane to facilitate the course correction, maintenance, refuelling and repair of spacecrafts on geostationary orbit. For this reason, the passenger carrier spaceplane would be equipped with a docking port and an airlock as well, and the spaceplane's life-support systems would be able to allow three astronauts to stay in space for at least two weeks.

The passenger carrier spaceplane would also be capable of destroying larger pieces of space debris thanks to its Canadarm robotic arm. The astronauts would only have to determine the course of the chosen space debris – e.g. of an unrepairable satellite –, capture it using the robotic arm, and keep it seized while towed to a lower Earth orbit where it could start descending back into the atmosphere. Such debris towing could be scheduled each time the passenger carrier spaceplane is on a mission to geostationary orbit in order to decrease the amount of space debris.

The propellant carrier spaceplane of Phoenix Program would specifically be designed for carrying liquid hydrogen and liquid oxygen rocket fuels, and would only be controlled remotely, thus, it would have neither crew nor pressurised cargo hold. However, the propellant carrier spaceplane's structure would have another significant difference from the other spaceplanes, as it would be provided with two liquid hydrogen tanks of different sizes and storage capacities. The smaller liquid hydrogen tank would only be used for the return journey, for manoeuvres to descend back into the atmosphere, and its size and storage capacity would be designed accordingly. The larger liquid hydrogen tank's fuel would be used to reach low Earth orbit and for course corrections to reach the International Space Station.



11. X-33 technology demonstrator for a Single-Stage-To-Orbit reusable launch vehicle (Artist's Concept) (Credit: NASA)

While the propellant carrier spaceplane would not have a cargo hold, it would still be equipped with cargo hold doors, the dimensions of which would match the larger liquid hydrogen tank, as this larger cryogenic tank could be removed from the spaceplane in the space. For this procedure, the International Space Station would capture the propellant carrier spaceplane using its Canadarm2 robotic arm. Once the cargo hold doors are opened, the spacewalking astronauts could remotely or manually close the valves of the previously depleted larger liquid hydrogen tank, and then disconnect the easily accessible tubes from the cryogenic tank: the tube transferring liquid hydrogen to the rocket engine of the spaceplane on the one hand, and the tube supplying helium to create the required overpressure on the other hand. Then, after unscrewing some fixing bolts, the cryogenic tank could be removed easily from the spaceplane.



12. Dream Chaser spaceplane (Artist's Concept) (Credit: Sierra Space)

This would allow the propellant carrier spaceplane to provide LOX/LH₂ rocket fuel supply constantly, and also to leave a large cryogenic tank with the International Space Station each time it visits space.

The propellant carrier spaceplane and its cryogenic tanks would be designed in such a way so as to the propellant carrier spaceplane, in order to reach low Earth orbit and manoeuvre to the International Space Station, would consume no more than one third of the rocket fuel it may carry overall. With this, beyond the amount required for the return, the propellant carrier spaceplane would have plenty enough liquid hydrogen and liquid oxygen left in its cryogenic tanks, from which the spacewalking astronauts, using a specially designed tube, could pump out the excess fuel through the standardised receptacle on top of the spaceplane's fuselage used for aerial refuelling.

1.3 Cryogenic Space Station Module

For the smoothness of supplying rocket fuel and for the implementation of the other parts of Phoenix Program, a new space station module would be designed, launched and connected to the International Space Station. This cryogenic space station module would allow pumping LOX/LH₂ rocket fuel out of the cryogenic tanks of the spaceplane, as well as to store those separately.

While the mothership would use its own turbopumps to fill the spaceplanes with hydrogen and oxygen in liquid state from the cryogenic tanks installed in its twin-fuselage, the International Space Station would pump out the excess hydrogen and oxygen – which is not needed for the return journey – from the spaceplanes in gaseous state. For this, the spaceplanes of Phoenix Program would

also be provided with a separate helium supplying valve on their standardised receptacles used for aerial refuelling.

This valve would connect to the helium gas loop of the pressure-fed, vacuum-optimised rocket engines of the spaceplanes, and the astronauts pumping out the LOX/LH2 rocket fuel would use this valve to pump helium, heated to several hundreds of Celsius degrees, from the cryogenic space station module into the partly depleted cryogenic tanks of the spaceplanes, ensuring overpressure for pumping the rocket fuels out completely. The coupling head used by the spacewalking astronauts for pumping out the LOX/LH2 rocket fuel would also serve as a heating unit, which would heat the liquid hydrogen and liquid oxygen – discharged through the standardised aerial receptacle as a result of the overpressure caused by the helium input – to gaseous state before pumped into the cryogenic space station module through the multitubular pipe connecting the coupling head and the International Space Station.



13. International Space Station (Credit: NASA)

The cryogenic space station module would use cryogenic distillation to separate the oxygen and the hydrogen from the helium – with which the former two were mixed in the cryogenic tanks of the spaceplane due to the overpressure –, and all three gases would be stored in separate tanks in liquid state. However, this ability of the cryogenic space station module to separate materials would be used on every liquid or gaseous material aboard the International Space Station, from carbon dioxide exhaled by the astronauts to nitrogen in the air of the International Space Station.



14. Whirlpool Galaxy (Credit: NASA)

For this exact reason, the cryogenic space station module would be much more than a simple space gas station; it would serve as a comprehensive storage- and distribution module, including the provision of the astronauts with oxygen, and, among others, even providing the International Space Station with water and emergency power supply by using hydrogen and oxygen in the fuel cells.

While the cryogenic space station module would primarily serve as a port for propellant carrier spaceplanes, every spaceplane version of Phoenix Program would be capable of pumping out rocket fuel in space. This would allow cargo- and passenger carrier spaceplanes returning from different missions to manoeuvre here before returning to the Earth, and to deplete every drop of excess LOX/LH2 rocket fuel which is not needed for descending back into the atmosphere.



15. Astronaut Steve Swanson on a spacewalk on the International Space Station (Credit: NASA)

The multitubular pipe of the cryogenic space station module, which the astronauts could use for these procedures, would not only be suitable for transferring gaseous hydrogen, oxygen and helium separately, but would also provide a data- and power link between the International Space Station and the currently connected spaceplane, allowing the constant monitoring and direct controlling of the devices of the given spaceplane while LOX/LH2 rocket fuel is pumped out, providing them with power from the International Space Station as well.

1.4 The Procedure of Aerial Launches

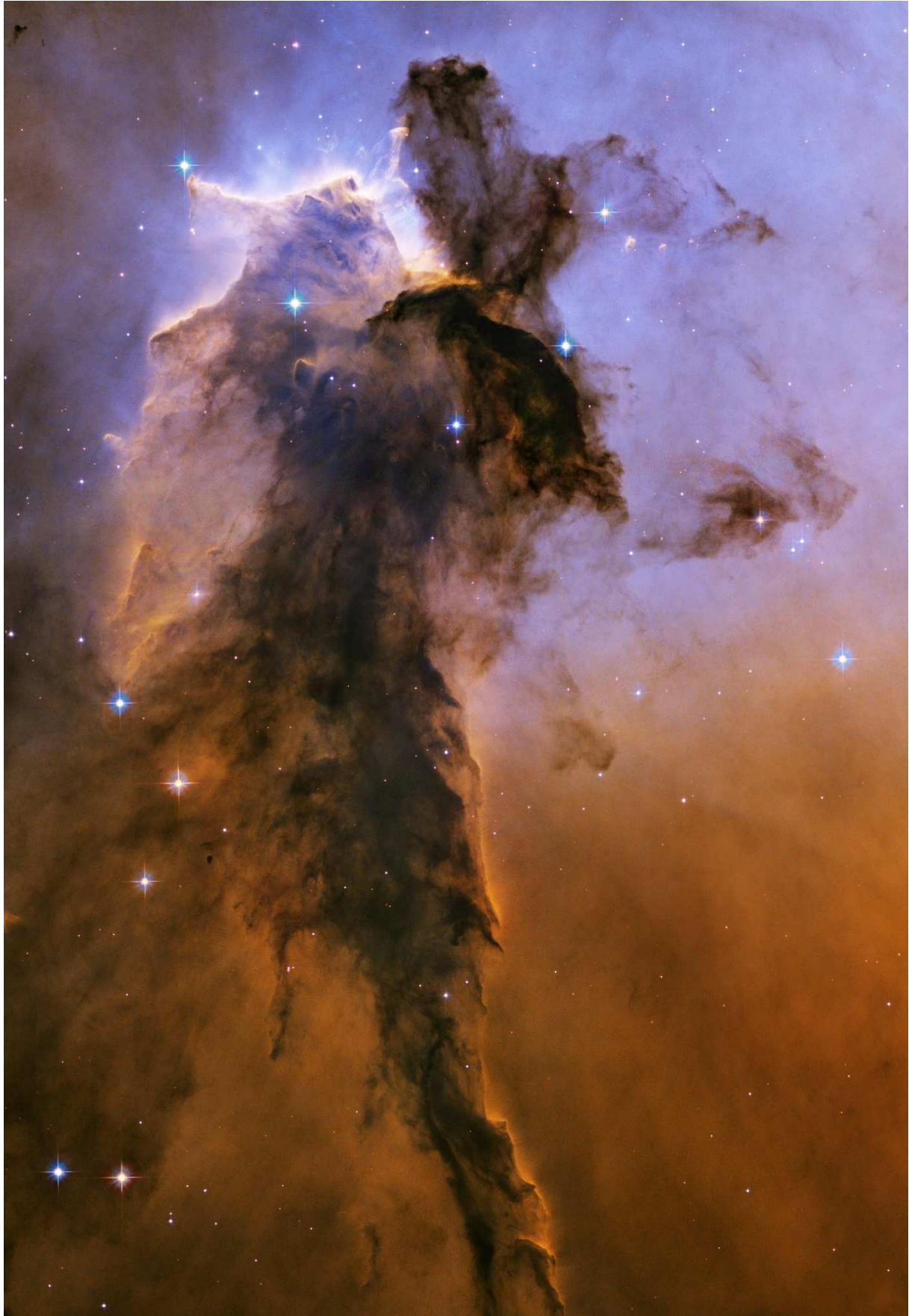
The Falcon 9 booster rocket redesigned for aerial refuelling and launch, as well as the reusable spaceplane of the appropriate version to be used for the specific mission would be connected to the refuelling- and fixing pieces of the load-carrying connector wing section of the mothership in a hangar next to the runway, but no part of the aerial launch vehicle system would be filled with rocket fuel yet.

Then an aircraft-towing ground vehicle would tow the mothership from the hangar to a rocket fuel refuelling spot at a safe distance from surface buildings, where the booster rocket would be refuelled with RP-1 kerosene, and the cryogenic tanks installed in the twin-fuselage of the mothership would be refuelled with liquid hydrogen and liquid oxygen. In the meantime, the tow plane would also be refuelled at a separate refuelling spot with traditional kerosene aviation fuel.



16. Johnson Space Center's Mission Control Center station flight control room (Credit: NASA)

Once all the required inspections are carried out, the aircraft-towing ground vehicle would tow the mothership to the beginning section of the runway, and then the tow plane in front of the mothership. The twin-fuselage, the airframe and the propellers actuated by electric motors of the tow plane would be the same as those of the mothership, however, a kerosene-fuelled gas turbine generator would also be installed in both of its fuselages, the overall performance of which would be enough to provide sufficient power for flying both the tow plane and the mothership.



17. Eagle Nebula (Credit: NASA)

The tow plane and the mothership behind it would be connected at the beginning section of the runway using the two high-voltage electric cables released parallelly by the tow plane. The tension of these electric cables would be regulated throughout the entire flight by an automated device.

One of the advantages of electric propulsion in case of the aircrafts is that a shorter runway would be enough for take-off thanks to the immediately achievable high RPM, offering a wider range of optional runways for launching the launch vehicles of Phoenix Program.



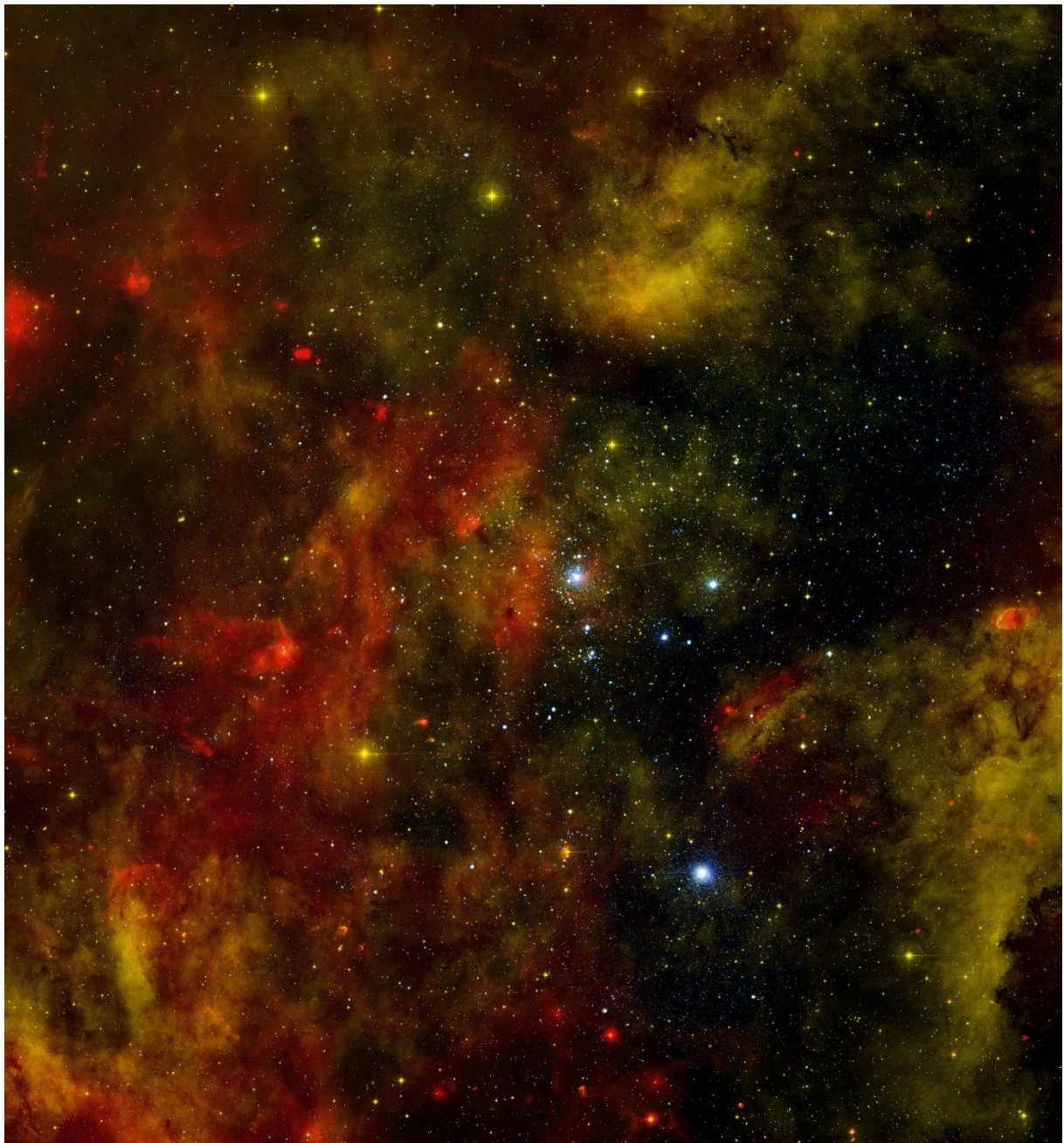
18. Space Florida Launch and Landing Facility (Credit: NASA)

The tow plane and the mothership would be connected through electric cables and take off closely behind each other, as the rolling of the two planes on the runway and the take-off would be synchronised by an autopilot developed specifically for this purpose within the framework of Phoenix Program. The cables connecting the tow plane and the mothership would not only transfer energy, but would also establish data link between the planes, ensuring the constant availability of all sensor data of both planes for the autopilot that keeps the two planes synchronised.

The tow plane and the mothership would fly in tandem towards the designated launch area; once this area is reached, the mothership would make circles in the air until both the Falcon 9 booster rocket and the spaceplane are fully refuelled from the cryogenic tanks installed in the fuselages of the mothership. The booster rocket would be filled with liquid oxygen through the refuelling- and fixing piece installed in the posterior load-carrying connector wing section of the mothership, while the spaceplane would be filled with liquid hydrogen and liquid oxygen through the refuelling- and fixing piece protruding from the anterior load-carrying connector wing section.

Refuelling the booster rocket and the spaceplane with the refrigerated liquefied gases in the air, directly before the launch, would minimise evaporation from the cryogenic tanks of the booster rocket and of the spaceplane, as the cryogenic tanks are provided with minimal thermal insulation due to weight efficiency.

Once all the final inspections are carried out, the tow plane and the mothership would turn towards the ideal orbit depending on the specific mission, and then, after the countdown, the mothership would release the launch vehicle filled completely with rocket fuels, so that the booster rocket, igniting nine Merlin 1D rocket engines, could head towards space, manoeuvring with the wings of the spaceplane to set itself into vertical position.



19. Young stars (Credit: NASA)



20. Artemis I in Moonlight (Credit: NASA)

To prevent the vertical stabilisers of the spaceplane from crashing into the anterior load-carrying connector wing section of the mothership when releasing the launch vehicle, the local refuelling- and fixing piece would also act as a hinged supporting fixture, capable of lowering the nose of the launch vehicle by two metres upon release, thanks to the weight placed on it. Once this hinged supporting fixture is open, it does not have to be able to support the related weight of the launch vehicle, because at the same time when the hinged supporting fixture opens completely as part of the release process, the launch vehicle would also detach from the mothership.

After launching the launch vehicle, the tow plane and the mothership, still connected through the electric cables, would return to the aerodrome of departure, however, the mothership would disconnect from the two parallel high-voltage electric cables to land on the runway separately as a glider. The tow plane would land after retracting the electric cables.



21. SpaceX Falcon 9 booster landing (Credit: SpaceX)

The Falcon 9 booster rocket, after releasing the spaceplane serving as the second stage, would also return to the aerodrome of departure, where it would brake using its rocket engines to land on its released landing legs. On missions where the rocket fuel required for returning to the aerodrome of departure had to be consumed to accelerate the spaceplane to reach high Earth orbit or to orbit a heavier payload, the booster rocket would land on an autonomous spaceport droneship (ASDS) of SpaceX.

Upon completing the mission, the spaceplane would also return to the aerodrome of departure, where possible; however, should it land on another aerodrome due to weather conditions or other reasons, the tow plane would tow the spaceplane back to the base aerodrome. For this, the tow

plane – similarly to the mothership – would also have fixing pieces on its load-carrying connector wing section for carrying the booster rocket and the spaceplane.

Since the weight of the booster rocket and of the spaceplane is minimal with empty rocket fuel tanks, the tow plane would not only take part in aerial launches, but also in logistical tasks between the manufacturing bases and the base aerodrome.



22. Aero Spacelines Super Guppy cargo aircraft (Credit: NASA)

For the maximum utilisation of the tow plane for such purposes, an externally suspended, aerodynamic cargo hold would be designed within the framework of Phoenix Program, which could be fixed to the refuelling- and fixing pieces of the load-carrying connector wing section of the tow plane in a way similar to a reserve fuel tank. The tow plane with a pressurised and heated externally suspended cargo hold would be able to carry out similar hauling tasks as the Super Guppy cargo aircraft.

1.5 Emergency Protocols

In case both high-voltage electric cables connecting the tow plane and the mothership were to break or release for any reason during the flight towards the designated launch area, before releasing the launch vehicle, the propellers of the mothership actuated by its own electric motors would be rendered inoperable due to the absence of energy supply, making the mothership unable to fulfil its role. In such case, two of the Merlin 1D rocket engines of the Falcon 9 booster rocket still fixed to the load-carrying connector wing section of the mothership would be ignited, allowing the mothership to

exploit the thrust of the Merlin 1D rocket engines with adjustable output and would return safely to the aerodrome of departure together with the unreleased launch vehicle.

Since liquid oxygen would only be transferred into the booster rocket and into the spaceplane during the aerial refuelling directly before launching the launch vehicle, the Merlin 1D rocket engines of the booster rocket would consume RP-1 kerosene directly from the booster rocket intended for the emergency return journey to the aerodrome of departure, however, liquid oxygen would be supplied from the cryogenic tanks installed in the fuselages of the mothership, through the refuelling- and fixing piece installed in the posterior load-carrying connector wing section of the mothership.



23. Rosette Nebula (Credit: ESA)

The structural strength of the refuelling- and fixing piece installed in the load-carrying connector wing section of the mothership would not only be designed to carry the weight of the completely refuelled launch vehicle, but also for the ignition of two Merlin 1D rocket engines without releasing the mothership.

Upon returning to the immediate proximity of the aerodrome of departure, all the remaining rocket fuel – i.e. liquid hydrogen and liquid oxygen in the cryogenic tanks of the mothership and RP-1 kerosene in the booster rocket – would be released into the air before landing for safety reasons, and then the mothership would land on the runway as a glider.



24. SpaceX Starman spacesuit (Credit: NASA)



25. Oshkosh Striker Aircraft Rescue and Fire Fighting vehicle (Credit: NASA)

In case of a risk of explosion or other hazards, pilots of both the tow plane and the mothership would be able to eject using the ejection seats deployable at any altitude. Consequently, similarly to the crew of the passenger carrier spaceplane, pilots of both the tow plane and the mothership would wear pressurised “Starman” spacesuits by SpaceX, allowing a safe descension even from an altitude of 10 kilometres where the air is thin. All the equipment in the cockpit of the tow plane and the mothership, from push buttons to touch screens, would be designed to be used in spacesuits.

Beyond its own rocket engine and LOX/LH2 rocket fuel supply used for orbiting and manoeuvring, the passenger carrier spaceplane of Phoenix Program would also be equipped with a solid-propellant rocket engine installed in the fuselage – similar to those installed in launch escape systems –, the powerful thrust of which could push the spaceplane to a safe distance from the booster rocket during its short combustion time. This emergency system would be operational at all times, even when the spaceplane is attached to the mothership, allowing the astronauts to escape quickly from the booster rocket and from the mothership at any time.

Since the solid-propellant rocket engine would be installed permanently in the fuselage of the passenger carrier spaceplane, this emergency system would be available not only for the aerial launch, but also for the entire period when the spaceplane is in space and when it returns, allowing, among others, for the solid-propellant rocket engine to ensure emergency braking – in case aerobraking manoeuvres were to fail – when the spaceplane, after having every drop of its liquid rocket fuel consumed, descends back into the atmosphere.

In case of an emergency similar to that of the Soyuz T-10-1 mission, when a disaster due to explosion is inevitable, it would be possible to engage the detachment of all the ejection seats and of the

spaceplane simultaneously with the push of a single button, thanks to the ejection seats in the tow plane and in the mothership, and to the launch escape system installed in the passenger carrier spaceplane.

The cargo carrier and propellant carrier spaceplanes of Phoenix Program would not be provided with solid-propellant emergency rocket engines – which are otherwise a significant extra weight. These spaceplanes could indeed use this solution to detach from the booster rocket and from the mothership before aerial launch, but could only use their own LOX/LH2 rocket engines to escape and reach the nearest aerodrome. Hence, in case an emergency requiring detachment were to occur before the spaceplane's refuelling with rocket fuel from the cryogenic tanks installed in the mothership would be initiated, the spaceplane could only land at an aerodrome the distance from which would allow reaching it by simple gliding.



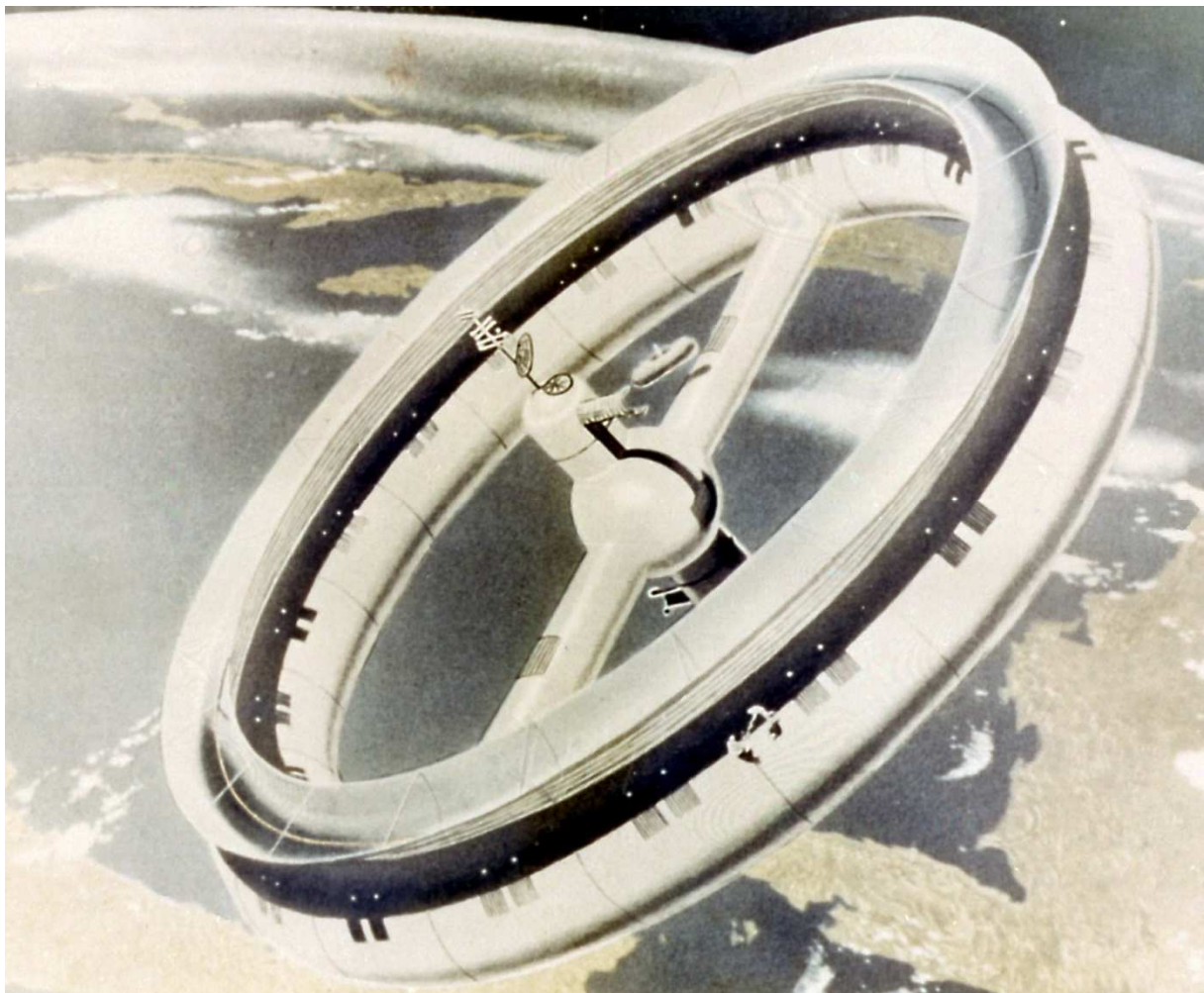
26. Our home, Earth (Credit: NASA)

Chapter 2: Gravity Ring as a Deep-Space Spacecraft

Countless plans were made in the past decades on sending astronauts to Mars, but all plans – including the landing on the surface of Mars – are practically unfeasible without artificial gravity. This is due to the fact that the human body suffers inevitable physiological deformations when months are spent in zero gravity, including muscular atrophy, osteoporosis and the weakening of the immune system, while landing and completing missions on Mars require astronauts in top shape both physically and mentally.

Beyond the inevitable physiological effects of zero gravity on the human body, there is, among others, a constant risk of injuries as well, since even the lightest injuries, which could be treated easily in hospitals on Earth, could be lethal to astronauts in zero gravity if they cannot reach an environment with gravity in time, which currently is only possible at the International Space Station, using the emergency escape vehicles fixed to the Station and available at all times.

Thus, one of the key elements of manned deep space missions is to construct a ring-shaped rotating device simulating gravity through centrifugal force, or expressed more simply, to construct a gravity ring, which could serve the manned deep space missions of several years as a space station and as a deep-space spacecraft at the same time.



27. Von Braun's Wheel Space Station (Artist's Concept) (Credit: NASA)

However, to prevent constant sensory disorders caused by Coriolis force from hindering the astronauts in performing their tasks and everyday activities, the gravity ring should have a diameter of at least 200 metres for a lower RPM to simulate gravity on Mars, which is only the third of the gravity on Earth.

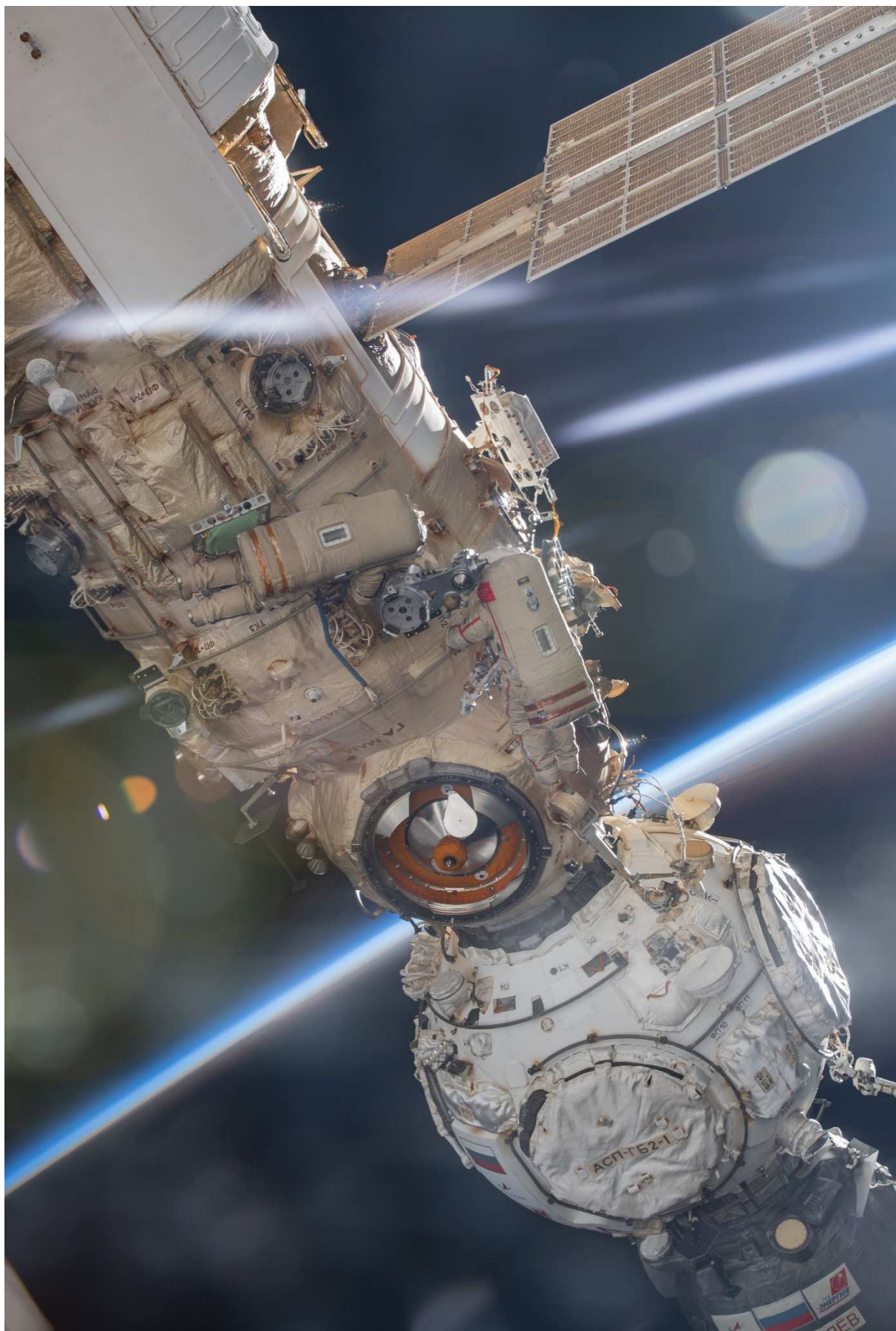
Another key element of conquering Mars is the cost-efficient orbiting of the necessary and large volumes of liquid hydrogen and liquid oxygen rocket fuels in order to accomplish all parts of a Mars mission, including the effective protection of the astronauts against cosmic ray, the provision of oxygen to the astronauts and braking with rocket engines to land on Mars.



28. Van Allen Probes in orbit to explore the radiation belts (Artist's Concept) (Credit: NASA)

Since the reusable spaceplanes of Phoenix Program would be provided with pressure-fed, vacuum-optimised rocket engines, the removable liquid hydrogen tank of the propellant carrier spaceplane would also be a pressure-tight cylindrical aluminium tank with a thick wall. Thus, not only the constant cost-efficient low Earth orbiting of LOX/LH₂ rocket fuel could be solved with the propellant carrier spaceplanes, but aluminium cryogenic tanks left at the International Space Station by the propellant carrier spaceplanes could also be used as proper constructional elements to construct a rotating space station with a diameter of 200 metres.

For starting the construction of the gravity ring, the International Space Station would be redesigned so that the cryogenic space station module developed within the framework of Phoenix Program could become a structural element on the side of the International Space Station, beyond the plane of which no other space station modules or solar panels would extend, because the construction of the gravity ring would start by connecting its central component to the cryogenic space station module of the International Space Station.



29. Roscosmos cosmonauts Oleg Artemyev and Denis Matveev on a spacewalk at the ISS (Credit: NASA)

2.1 Construction of the Gravity Ring

Since constant sensory disorders caused by Coriolis force would afflict the astronauts in the smallest degree along the outer rim of a rotating space station, and the effect would intensify towards the centre, the space station modules of different purposes should be connected to the outer rim of the rotating space station. Only those components and space station modules would be located in the middle of the structure of the gravity ring which do not require the presence of astronauts throughout the entire period of a complete deep space mission, including the risk of repairs needed in case of any malfunctions.

The latter is crucial because any repairs of the components and space station modules in the middle of the structure of the gravity ring by the astronauts would require to stop the gravity ring completely, sacrificing a significant amount of rocket fuel for braking and also for restarting the rotation of the gravity ring after the repairs.



30. Keyhole Nebula (Credit: NASA)

The first four cryogenic tanks carried by the propellant carrier spaceplanes could be fixed to the central component of the gravity ring by angles of 90 degrees. After this, more and more cryogenic tanks would be connected longitudinally to the first four cryogenic tanks, one behind another, creating the four 100-meter-long spokes of the gravity ring of the cylindrical cryogenic tanks. These spokes would be connected through high-tensile wire ropes during the construction to ensure their stability until the outer, ring-shaped structure of the gravity ring is completed.

Beyond the metal handles for fixing the wire ropes, each cryogenic tank would also be provided with a longitudinal line of handrails corresponding to the rungs of a ladder. These metal handles and

handrails would allow astronauts to remove the cryogenic tanks easily from the propellant carrier spaceplanes, and would also provide a safe gripping and a place to fix themselves with a rope during the spacewalks when constructing the gravity ring, placing the cryogenic tanks one after another, and fitting the space station modules in their place.



31. Marshall Space Flight Center Neutral Buoyancy Simulator (Credit: NASA)

As soon as the four-pronged structure – stabilised with wire ropes – has reached a length of 100 metres in all four directions, further cryogenic tanks would be connected sideways from the end of each prong, one after another, creating the outer, ring-shaped structure. Since the cryogenic tanks serving as structural parts of the gravity ring would be long and cylindrical, the construction of the gravity ring would not result in a perfect ring, but in a polygon, supported by four spokes.

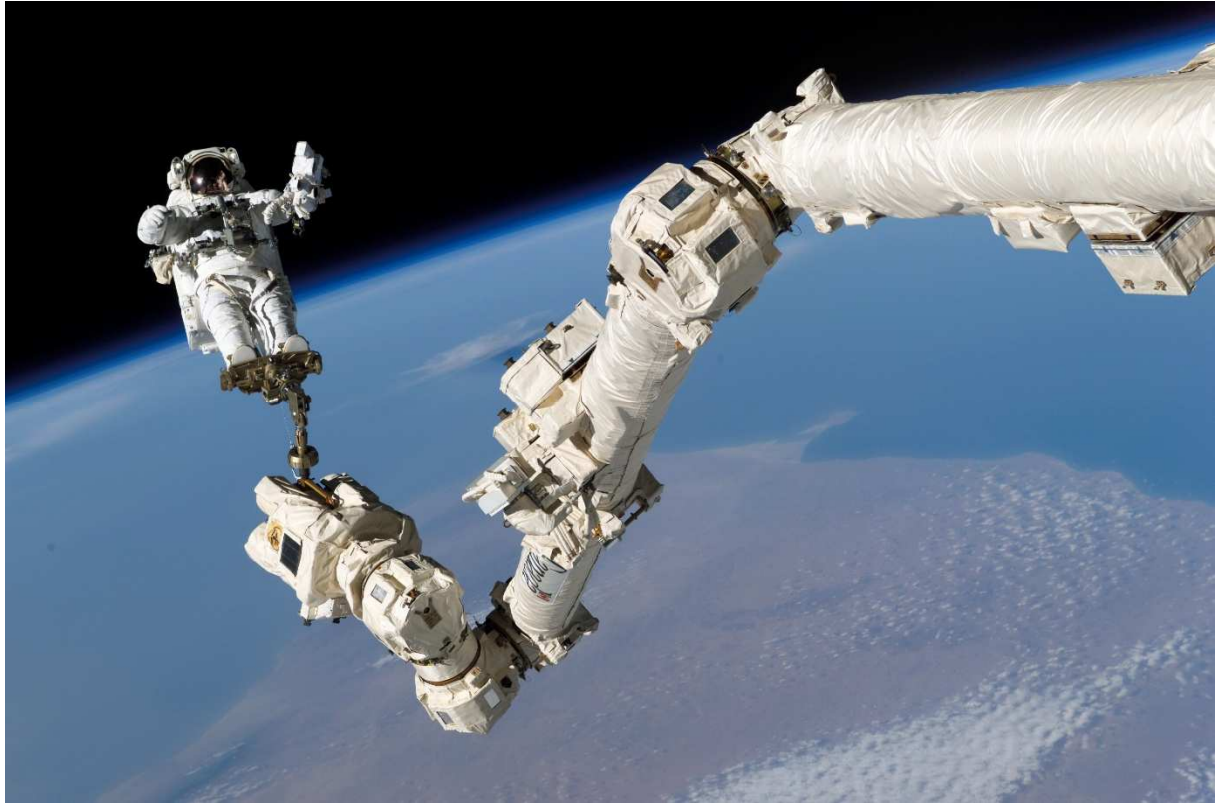
A connector would be installed between each cryogenic tank during the construction of the gravity ring, and therefore, the cryogenic tanks would practically not be connected directly to each other, but to these connectors. Several different versions of connectors would be available, which would be installed according to the angle which two connected, adjacent cryogenic tanks should form. For example, the connectors at the ends of the spokes of the gravity ring would be like a 3-way, T-shape adaptor plug.

Simultaneously with the construction of the entire gravity ring structure using cryogenic tanks, one side of the gravity ring would also be covered with solar panels. These would be iROSA solar panels with a large surface area, the same as used by the International Space Station, and would be fixed to the connectors between the cryogenic tanks using a hinge, allowing the rotation of the solar panels in an angle of 90 degrees.



32. Andromeda Galaxy (Credit: NASA)

The hinges would have two purposes: on the one hand, the hinges would make it possible to produce energy when the gravity ring is not properly facing towards the Sun with its solar-panel-covered side; and on the other hand, the hinges would ensure the changing of light and darkness required for the operation of the gas distribution system which ensures the stable rotation of the gravity ring.



33. Astronaut Stephen K. Robinson on a spacewalk at the International Space Station (Credit: NASA)

At the manufacturing stage, several electric and data cables would already be installed in the walls of the aluminium cryogenic tanks serving as structural parts of the gravity ring, and the connectors allowing the connection of the cryogenic tanks would not only ensure structural stability, but a comprehensive link between the cryogenic tanks. Thus, connecting the cryogenic tanks using the connectors would establish the power- and data network of the gravity ring as well.

2.2 Stabilisation Gas Distribution System

Since space station modules of different purposes would be connected to the outer rim of the gravity ring to minimise constant sensory disorders caused by Coriolis force, the centre of mass of the gravity ring would be in its structural centre, and the centre of mass of the gravity ring would also be changing constantly throughout the deep space missions depending on the current number of spacecrafts and Mars landers docked at the gravity ring.

For this reason, a gas distribution system would be responsible for the stability of the rotation of the gravity ring, capable of distributing the several hundred tonnes of liquid hydrogen and liquid oxygen rocket fuels required for the Mars mission in the cryogenic tanks serving as structural parts of the gravity ring in gaseous state.

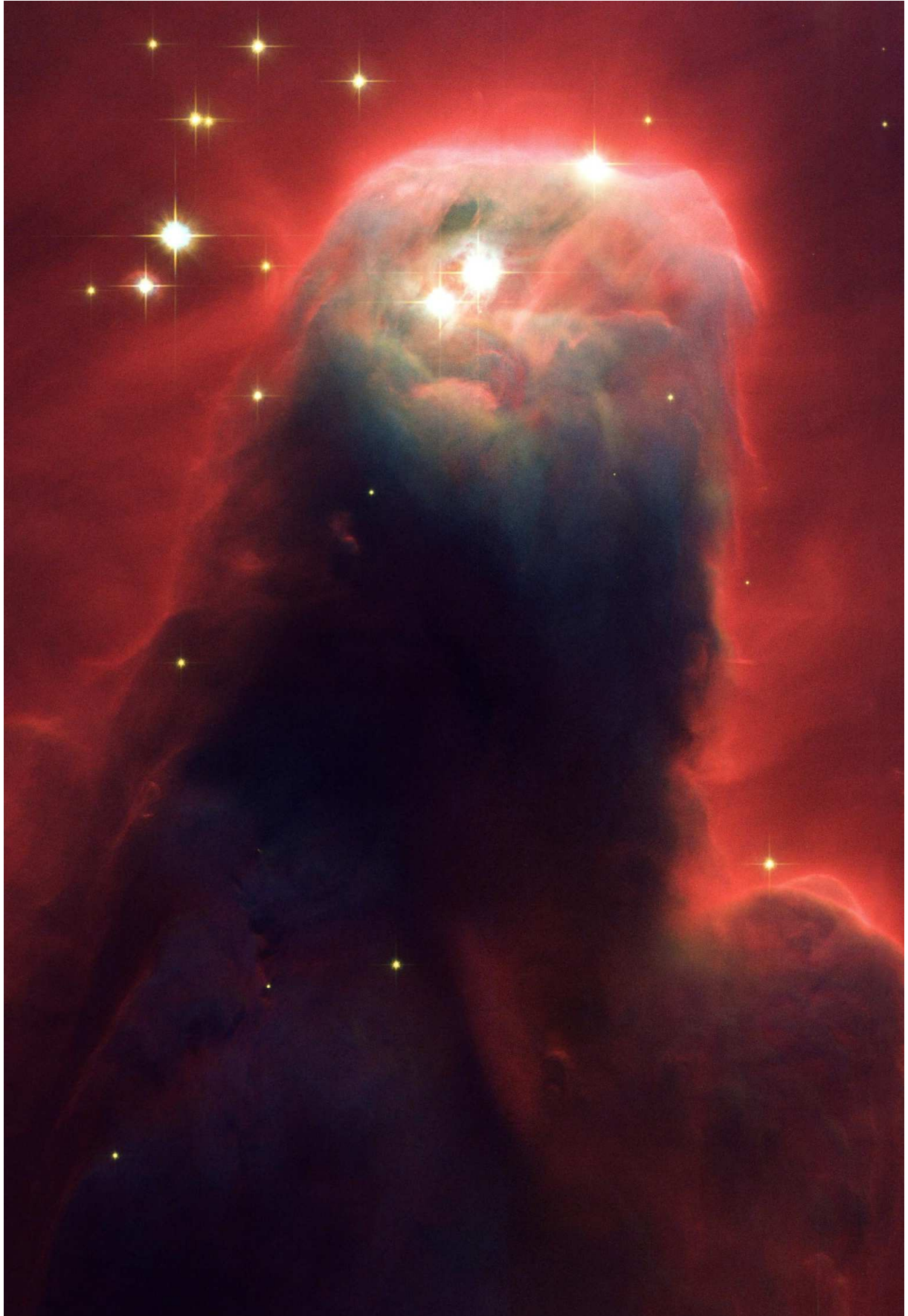
Since the original purpose of the cryogenic tanks used for the construction of the gravity ring is to supply the pressure-fed, vacuum-optimised rocket engine of the propellant carrier spaceplane with liquid hydrogen, these cryogenic tanks would have two valves at each end due to the operation of the spaceplane: one valve would supply liquid hydrogen towards the rocket engine of the spaceplane, while the other would provide helium to ensure the pressure required by the former process.



34. Omega Nebula (Credit: NASA)

The connectors allowing the connection of the cryogenic tanks – serving as structural parts of the gravity ring – would already have the pipelines installed inside, which, by the connection of the connectors and the valves at the ends of the cryogenic tanks, would turn the gravity ring into a gas storage construction with a massive storage capacity, while the opening and closing of the valves could be controlled remotely from the cryogenic space station module.

The cryogenic space station module itself would also have some liquefied hydrogen and liquefied oxygen storage capacity and a required cooling system, however, as soon as the first cryogenic tanks are connected to the central component of the gravity ring during the construction of the gravity ring, the hydrogen and oxygen drained in gaseous state from the propellant carrier spaceplane would be stored in these cryogenic tanks.



35. Cone Nebula (Credit: NASA)

This transfer, however, would not be performed directly from the propellant carrier spaceplanes to the cryogenic tanks – serving as structural parts of the gravity ring –, because the cryogenic space station module would first separate the helium gas which has been mixed previously with hydrogen and oxygen using cryogenic distillation. The so-obtained helium gas would then be liquefied and stored in the cryogenic space station module.

As the four spokes of the gravity ring would connect to the outer ring-shaped structure, the spokes would also divide the outer structure to four equal arcs, and since hydrogen and oxygen should be stored separately, two of the four spokes making the four-pronged structure of the gravity ring would be used for storing hydrogen, while the remaining two would be used for storing oxygen, including the related arcs from the outer ring-shaped structure of the gravity ring.

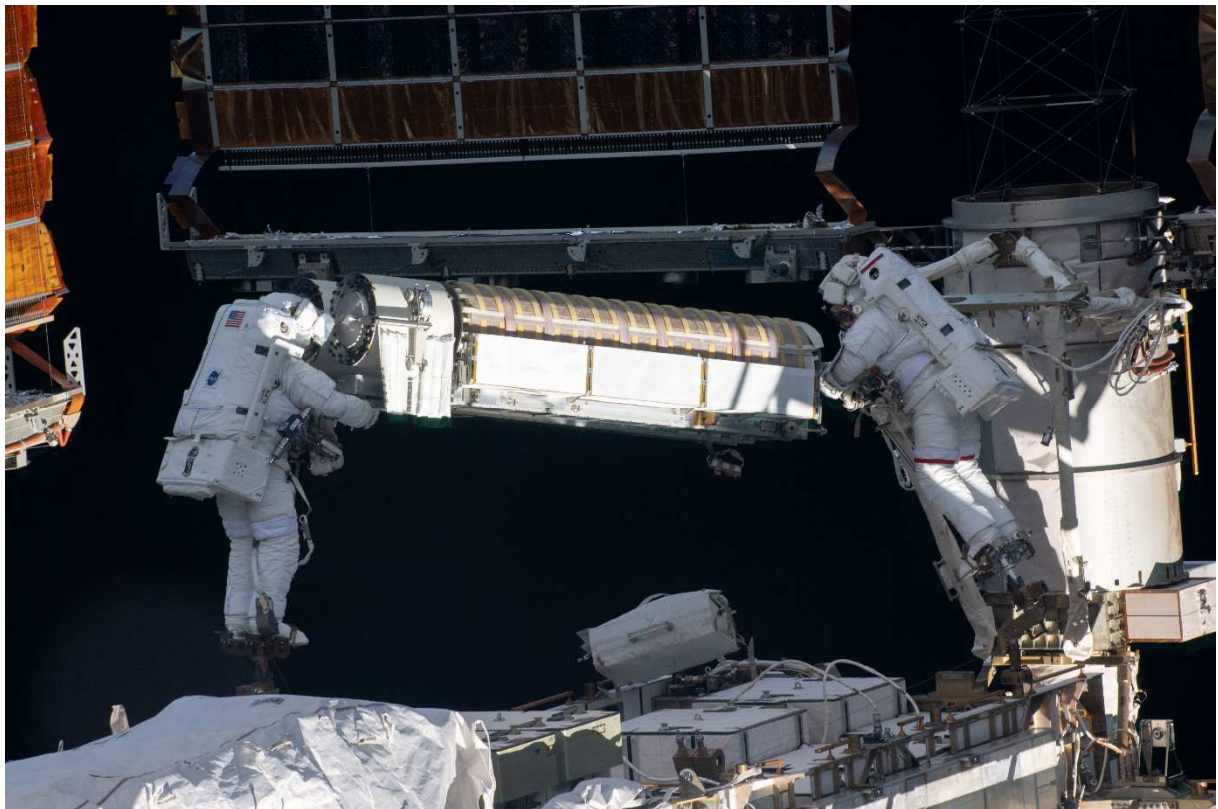


36. Madrid Deep Space Communications Complex (Credit: NASA)

When distributing hydrogen and oxygen for storage among the spokes and the related arcs of the gravity ring, opposing spokes and arcs would store the same gas. The purpose of this solution is to make both hydrogen and oxygen available at the ends of the spokes of the gravity ring, where the spokes join the ring-shaped cryogenic tank structure through the T-shaped connectors, allowing those space station modules to connect to these points of the gravity ring which need both hydrogen and oxygen for operation.

Since the cryogenic tanks used for the construction of the gravity ring wouldn't have their own cooling system, and direct sunlight could quickly warm up the aluminium wall of the cryogenic tanks, the hydrogen and oxygen stored in the cryogenic tanks of the gravity ring would liquefy and vaporise into gas again depending on whether the Earth currently casts a shadow on the International Space Station on low Earth orbit or not.

However, during the construction of the gravity ring, its iROSA solar panels would also be put in place consistently, and the International Space Station together with the gravity ring under construction would be rotated into a position so that the solar panels mounted on the gravity ring would cast a constant shadow on the cryogenic tanks serving as structural parts.



37. Astronauts Shane Kimbrough and Thomas Pesquet on a spacewalk at the International Space Station (Credit: NASA)

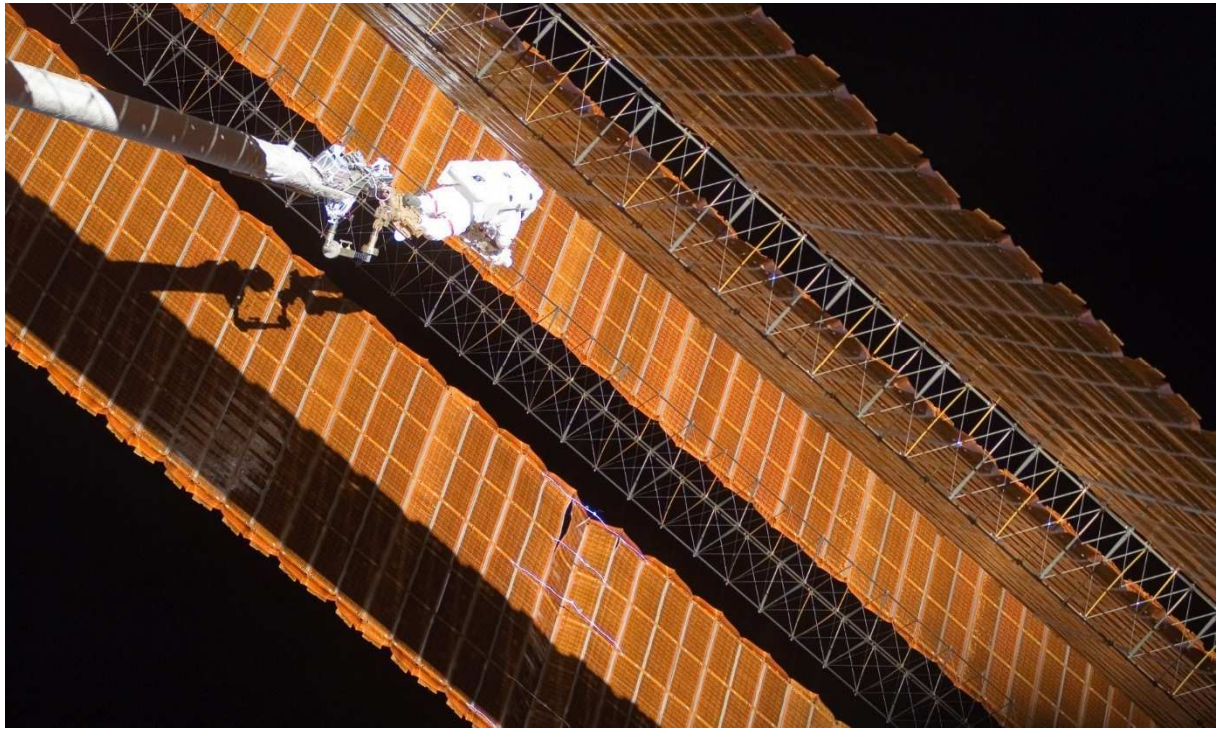
Therefore, the hydrogen and oxygen transferred in gaseous state from the cryogenic space station module to the cryogenic tanks of the gravity ring would be cooled constantly and converted into liquid state in the absence of any heat sources – e.g. direct sunlight –, allowing storage in large volumes, and at the same time, providing space for another batch of LOX/LH2 rocket fuel delivered by the next propellant carrier spaceplane.

Thus, not only the simple storage of the total volume of the rocket fuel required by the Mars mission could be solved, but the several hundred tonnes of oxygen and hydrogen stored in liquid state would also mitigate the forces occurring as a result of the rotation of the gravity ring, similarly to water towers installed on top of tower blocks.

Since the LOX/LH2 rocket fuel to be stored would not be transferred as liquid, but in gaseous state from the cryogenic space station module, the distribution of hydrogen and oxygen among the cryogenic tanks of the gravity ring could also be simplified, as the amount of hydrogen and oxygen

gases to be stored at a time would be distributed evenly among the selected cryogenic tanks through the remote opening of the valves of the pipelines connecting the cryogenic tanks behind one another.

However, the even distributability of LOX/LH2 rocket fuel among the cryogenic tanks is effective throughout the construction of the gravity ring only, as once the gravity ring is completed and its rotation has been initiated, the several hundred tonnes of rocket fuel stored in the cryogenic tanks would also be used to adjust the perfect weight distribution of the gravity ring.



38. Astronaut Scott Parazynski on a spacewalk at the solar wing of the International Space Station (Credit: NASA)

To this end, a remotely controlled, low-performance pump would also be installed in each of the connectors between the cryogenic tanks, so that in case the weight distribution of the gravity ring should be changed, or some of the LOX/LH2 rocket fuel stored in the cryogenic tanks should be used for course corrections, the required amount of hydrogen or oxygen could be vaporised with direct sunlight by rotating the iROSA solar panels in an angle of no more than 90 degrees, and then, the hydrogen and oxygen could be transferred easily to their destination using the pumps installed in the connectors. Once the operation is completed, the solar panels would be rotated into their original position, and the hydrogen and oxygen in the cryogenic tanks, previously converted into gaseous state, could cool down again and convert into liquid state.

2.3 Manoeuvring in Deep Space

The primary course correcting ability of the gravity ring would be provided by an engine module with a performance allowing to move the gravity ring from low Earth orbit, the rocket engine of which would be fuelled by gaseous hydrogen and oxygen. This course correction engine module would be connected to the central component of the gravity ring, on the opposite side of the cryogenic space station module.

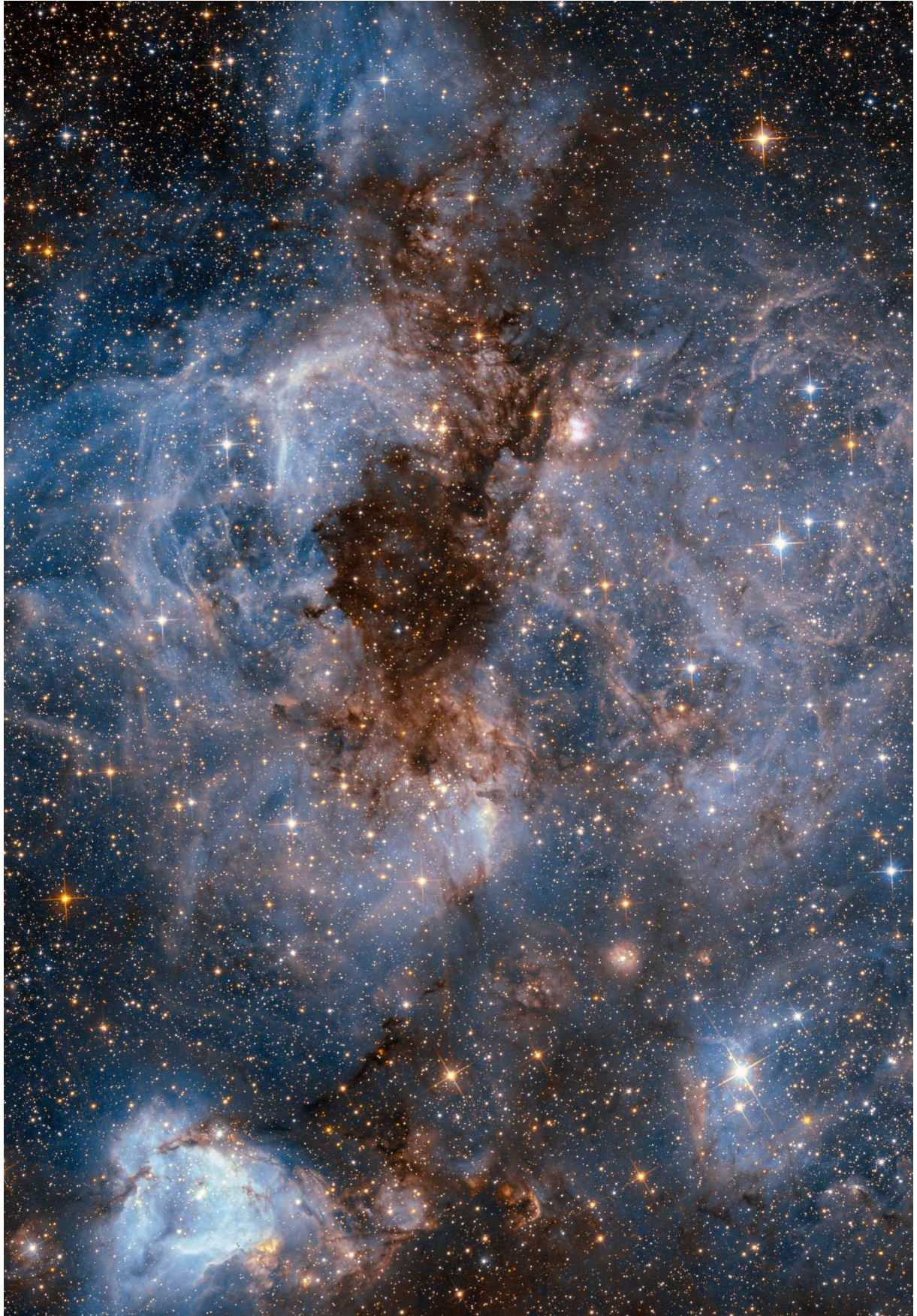


39. Test pad of Marshall Space Flight Center (Credit: NASA)

Since the cryogenic space station module itself would also have some LOX/LH2 rocket fuel storage capacity, it would not be strictly necessary to convert some of the LOX/LH2 rocket fuel stored in the cryogenic tanks of the gravity ring into gas for using the course correction engine module, which simplifies the use of the course correction engine module. The LOX/LH2 rocket fuel storage capacity of the cryogenic space station module would be sufficient not only for minor deep space manoeuvres, but also to move the gravity ring from low Earth orbit and to achieve second cosmic velocity to escape the gravity of the Earth.

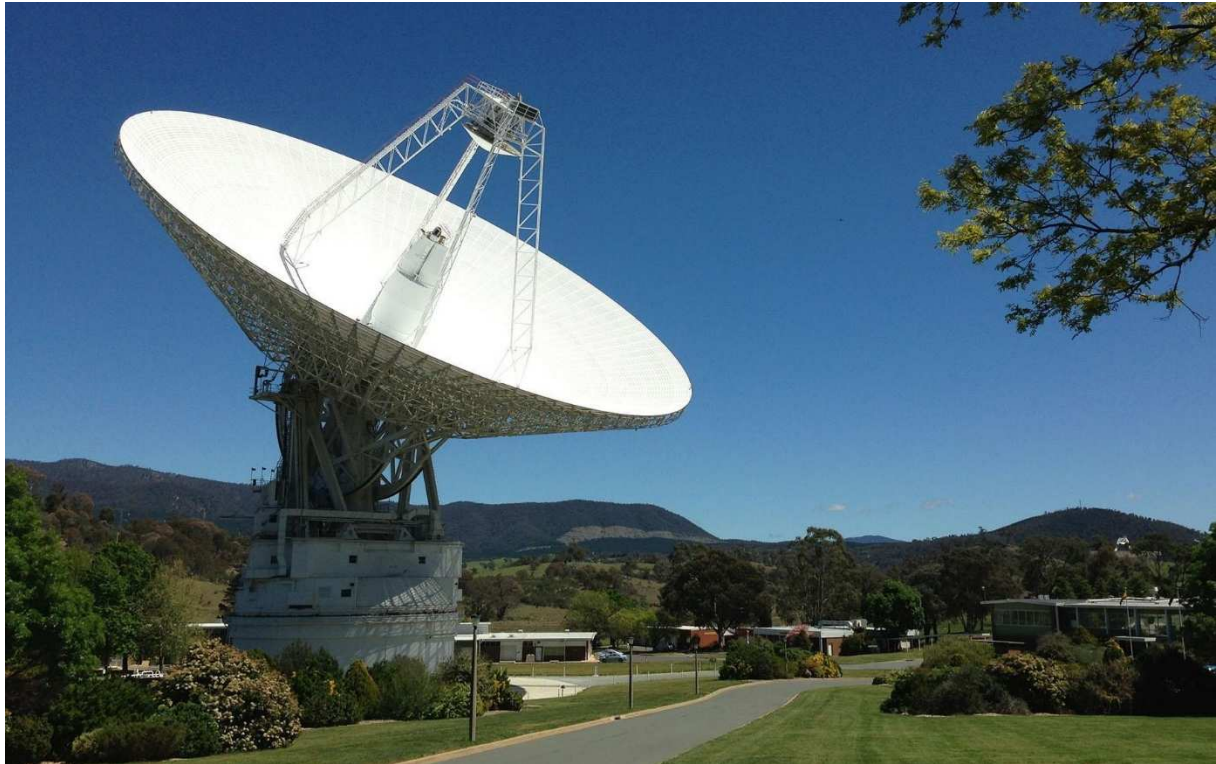
Using liquid hydrogen and oxygen would provide the rocket engine with a much more powerful thrust for the course correction engine module than using gaseous hydrogen and oxygen, but this solution is less significant in the case of deep space manoeuvres – such as entering geostationary orbit when reaching Mars –, and supplying hydrogen and oxygen in gaseous state would also give a chance to use up high-pressure hydrogen and oxygen gases in the course correction engine module before the critical pressure would exceed the tolerance level of the cryogenic tanks in case of an emergency, for example, in case of a control failure of the iROSA solar panels, when the direct sunlight were to render the vaporisation of the LOX/LH2 rocket fuel stored in the cryogenic tanks of the gravity ring unavoidable.

In case of a similar emergency, this solution would make it unnecessary to simply release hydrogen and oxygen gases into space in order to reduce overpressure in the cryogenic tanks, and even though the premature or entirely unnecessary consumption of a specific amount of rocket fuel for accelerating or decelerating the gravity ring would change the parameters of the Mars mission fundamentally, this definitely would not entail risking the lives of the astronauts, as in worst case scenario, the mission would merely be cancelled and the astronauts would simply use this rocket fuel to return to Earth.



40. Large Magellanic Cloud (Credit: NASA)

For starting and, if necessary, for stopping the rotation of the gravity ring, each of the T-shaped connectors at the ends of the four spokes fixing the structure of the gravity ring would be equipped with a manoeuvring engine module with a performance much lower than that of the course correction engine module. Since the cryogenic tanks making the outer ring-shaped structure of the gravity ring would branch off in two different directions at the T-shaped connectors at each end of the spokes, and the hydrogen and oxygen would be stored alternatingly in the four arcs of the gravity ring divided by the spokes, both hydrogen and oxygen would be available at the T-shaped connectors of the gravity ring to supply the rocket engines of the manoeuvring engine modules.



41. Canberra Deep Space Communication Complex (Credit: NASA)

The rocket engines of the manoeuvring engine modules connected to the T-shaped connectors of the gravity ring would also be fuelled by gaseous hydrogen and oxygen, however, these rocket engines would be unique with regard to the nozzles, which could be rotated in a minimum angle of 90 degrees, allowing the execution of complex manoeuvres with the gravity ring which may require minimal thrust.

Since the cryogenic space station module would be connected to the structural centre of the gravity ring, and the manoeuvring engine modules would be connected to the T-shaped connectors at the ends of the spokes of the gravity ring, the four manoeuvring engine modules could only be supplied with hydrogen and oxygen stored in the cryogenic tanks of the gravity ring through the T-shaped connectors.

Beyond the main course correction engine module and the four manoeuvring engine modules with smaller thrust, the gravity ring would also have a manoeuvring nozzle network only to be used in case of an emergency.

As the constant rotation of the gravity ring simulates gravitation for the astronauts, liquid hydrogen and oxygen stored in the cryogenic tanks making the spokes of the gravity ring accumulates in the cryogenic tanks close to the outer rim of the gravity ring, so that liquid hydrogen and oxygen stored in the cryogenic tanks making the spokes of the gravity ring could be accessed without vaporisation by exploiting centrifugal force resulting from the rotation.

This is what the emergency manoeuvring nozzles would exploit. Each of the connectors between the cryogenic tanks making the spokes of the gravity ring would be equipped with a nozzle, together with the related low-performance electrical heating unit and compressor. Since hydrogen and oxygen would be stored separately, only one of the gases would be accessible through these connectors at a time, and the emergency manoeuvring nozzles would not burn, but heat the currently accessible hydrogen or oxygen to gaseous state, pressurise it with their compressors and then generate thrust by releasing these gases through the nozzles at a high speed.



42. Astronauts Daniel C. Burbank and Steven G. MacLean on a spacewalk at the International Space Station (Credit: NASA)

Due to limited capabilities and low efficiency, this manoeuvring nozzle network would only be used in emergencies, when an accurate manoeuvre should be executed immediately and there is no time to rotate the iROSA solar panels to vaporise liquid hydrogen and oxygen stored in the cryogenic tanks to supply the manoeuvring engine module.

2.4 A Safe Habitat in Deep Space

The threats posed by deep space to astronauts on a Mars mission can never be exaggerated. Astronauts might be several ten million kilometres away from any help, exposed constantly to cosmic ray which may damage living organisms, dreading extremely high-speed micrometeorite impacts, while even a single solar flare hitting the deep-space spacecraft directly may deliver a lethal dose of radiation to the whole crew.

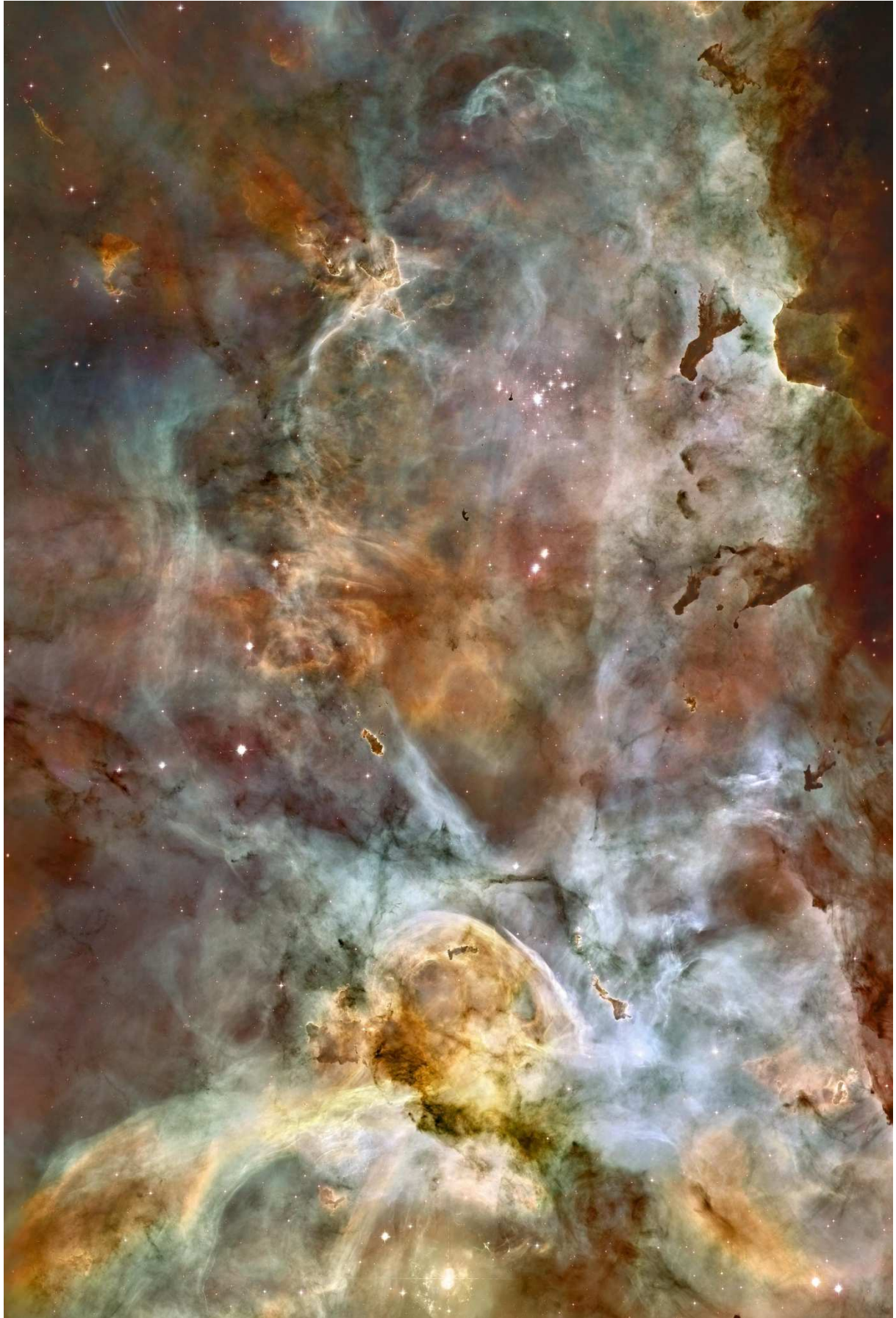
For this reason, Phoenix Program would develop a space habitat module connected to the outer rim of the gravity ring, which would reduce risks to an acceptable level and provide a safe habitat for the astronauts throughout the entire Mars mission. This space habitat module would consist of two main parts: the crew module and the shield module.



43. Space Launch System super heavy-lift launch vehicle (Credit: NASA)

The crew module would basically be a space station module serving as a habitat for the astronauts, similar to the one designed for the International Space Station with a traditional layout, however, the crew module would be prepared for constant artificial gravity, and would also be equipped with a complex control system so that the astronauts could always monitor and remotely control the gravity ring, all its space station modules, the spacecraft and all the other equipment.

The crew module would be equipped with every necessary device from the kitchen to the toilet and the shower to the cabins, so that a maximum of six astronauts could have a tight but comfortable environment throughout a Mars mission, which may take up to two years. The dimensions and weight of the crew module would be consistent with the maximum payload to be set on low Earth orbit by Space Launch System super heavy-lift launch vehicle.



44. Dark Clouds of the Carina Nebula (Credit: NASA)

The crew module itself would only be provided with a minimal protection against micrometeorites and radiation, as each usable kilogram would be exploited to increase the habitat and the number of devices to be installed, and even the capacities of the life-supporting systems of the crew module – from oxygen supply to heating – would be able to provide only a short emergency operation, as the life-supporting systems of a deep space mission would be located in a separate life-supporting space station module connected to the space habitat module.

The micrometeorite- and radiation protection of the crew module would be provided by the other main part of the space habitat module, that is, by a separate shield module, which would be a custom version of the large inflatable space station modules of Bigelow Aerospace to be developed within the framework of Phoenix Program.



45. B330 Inflatable space habitat module (Artist's Concept) (Credit: Bigelow Aerospace)

In the middle of the cylindrical shield module based on Bigelow Aerospace technology, there would be a completely free inner space with a diameter of at least ten metres; this is where the crew module would be placed, so that there would be another free space of at least three metres between the inner wall of the inflated shield module and the outer wall of the crew module, providing further habitat for the astronauts. Wire ropes would be used to tether the crew module and fix it in the middle of the shield module which would have a much bigger free inner space than the dimensions of the crew module.

Between the multi-layered outer wall of the shield module – partially made of Vectran, which is stronger than Kevlar – and the inner wall surrounding the habitat of the astronauts, there would be two more completely separated protective layers. The approximately half-metres-wide inner protective layer would be filled with a protective material made of a dilatant liquid, in which, shear rate and viscosity would increase at the same time, similarly to materials used in liquid shields.

The other outer protective layer of the shield module would have a diameter of approximately two metres and would be filled with compressed nitrogen gas; this high-pressure nitrogen gas would be stored in smaller cells connected through remotely controlled valves.

Beyond significantly decreasing the dose of cosmic ray afflicting the astronauts, the inner protective layer of the shield module filled with viscous-dilatant liquid would also be intended to block micrometeorites capable of piercing the outer casing of the shield module. The high-pressure nitrogen gas in the outer protective layer of the shield module would be intended to provide the astronauts with sufficient time to execute emergency protocols in case a micrometeorite were to crash into and pass through the shield module, and even pierce the wall of the crew module tethered inside the shield module.

In the latter case, the micrometeorite would also pass through some cells filled with high-pressure nitrogen gas, which means that, instead of the air of normal atmospheric pressure in the habitat of the astronauts, first it would be the high-pressure nitrogen gas of several atmospheres inside the damaged cells in the outer protective layer of the shield module to be ejected into space. This high-pressure nitrogen gas would not only be released into space until pressure is compensated, but would also be mixed with the air in the crew module with a pierced wall, but since nitrogen is safe to breathe and wouldn't fuel any fires either, nitrogen is the least hazardous to be used as protective layer for the astronauts.



46. A night on the International Space Station (Credit: ESA)

Regardless of the above, since excessive nitrogen would displace oxygen and would cause asphyxia and then death, the first thing for the astronauts to do in case of a casing damage would be to put on an emergency oxygen mask.

The cells making the outer protective layer of the shield module would be sized to prevent high-pressure nitrogen gas inside to reach a pressure level that might risk the astronauts, but at the same time, it could delay the leakage of air from the crew module with a pierced wall into space as long as possible.



47. Orion Nebula (Credit: NASA)

There would be six emergency cabins in the crew module to give astronauts a chance of survival in case one bigger or several smaller casing damages on the shield module or on the crew module would be so severe that pure vacuum could occur within minutes. Emergency cabins would be single-person, shower-stall-sized, pressure-tight tanks with doors specifically designed for opening and closing in a flash. Each emergency cabin will have a SpaceX Starman spacesuit inside, and while the emergency cabins would be tight, but would still have just enough space to put on these spacesuits.



48. Skylab Space Station Cluster in Earth's orbit (Artist's Concept) (Credit: NASA)

The astronauts would be able to check which emergency cabins are intact in case of multiple casing damages caused by micrometeorite impacts, as each emergency cabin would have its door closed by default with overpressure inside, which would be indicated by the constant colour signalling of a high-intensity LED light.

The emergency cabins would be made of fireproof material, and in case the smoke detector were to go off, the emergency cabins would also give an audible alarm to aid the sense of direction of the astronauts in case of poor visibility. Each emergency cabin would be equipped with a communication terminal and with a control panel for the fire extinguishing system of the space habitat module, but in case of a quickly spreading fire that threatens the lives of the astronauts directly, each emergency cabin would also be equipped with a special switch to release air from both main parts of the space habitat module – from the crew module and from the shield module – directly into space in order to create vacuum and to extinguish the fire immediately.

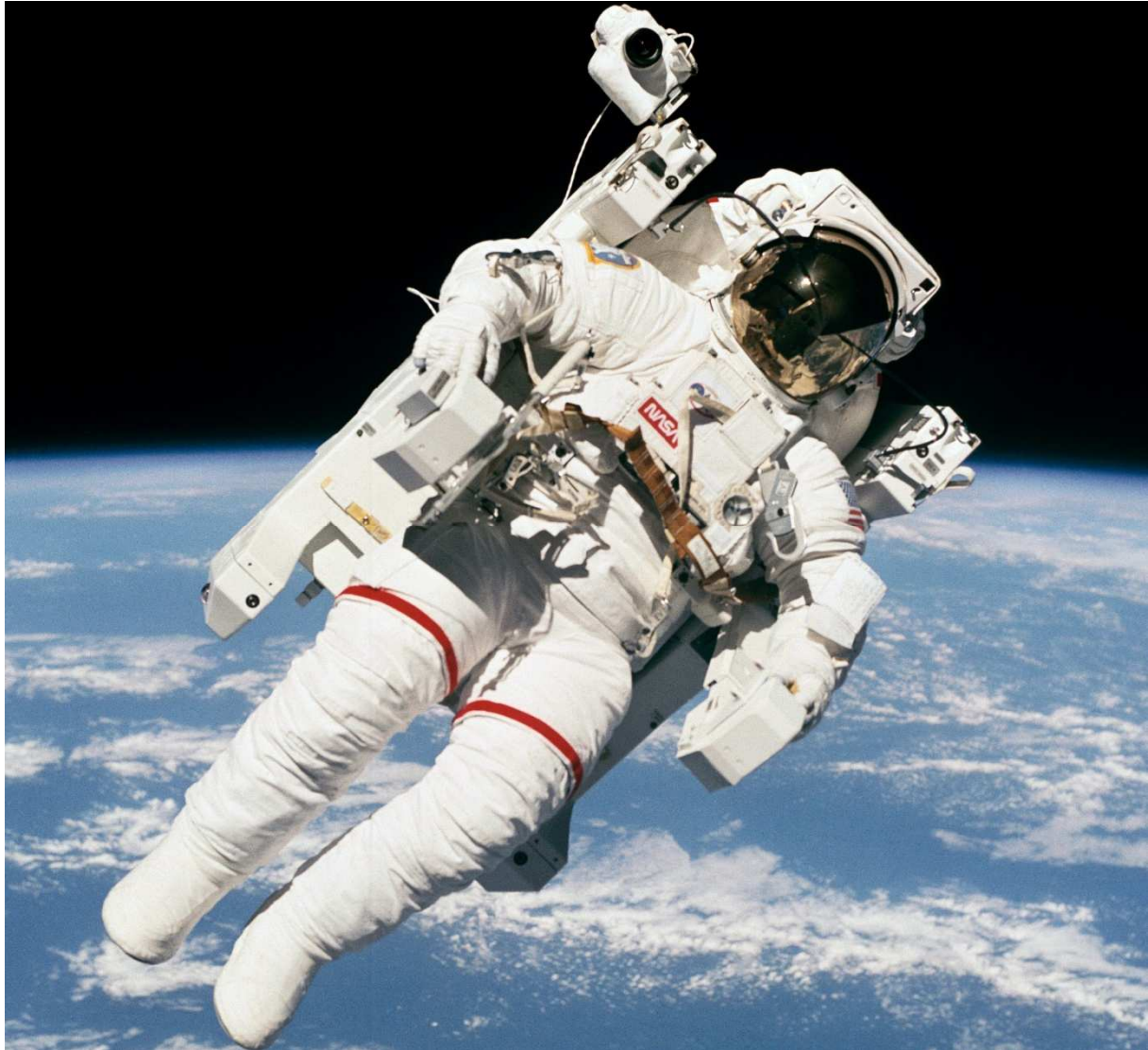
The folded shield module would be launched to the gravity ring on low Earth orbit using a SpaceX Falcon Heavy launch vehicle, where it would be inflated after connection to the outer rim of the gravity ring. In order to fix the space station module of the largest weight to the gravity ring by maintaining this module's stability after starting the rotation of the gravity ring, the shield module, having a diameter multiple of the size of the cryogenic tanks serving as structural parts of the gravity ring, would be fixed to these cryogenic tanks on several places using wire ropes.



49. Launching SpaceX Falcon Heavy launch vehicle (Credit: SpaceX)

When using SpaceX Falcon Heavy launch vehicle to launch the shield module, the shield module would already have the amount of liquid nitrogen in a cryogenic tank it requires for filling the cells in the outer protective layer, and the same nitrogen would be used to inflate the folded shield module to its full size. However, the dilatant liquid of several hundred tonnes of total weight for filling the inner protective layer of the shield module would be delivered in multiple instalments by the reusable cargo carrier spaceplane of Phoenix Program.

After this, the crew module to be launched with the Space Launch System super heavy-lift launch vehicle would be installed inside the shield module. For the achievability thereof, one end of the cylindrical shield module would be provided with a circular pressure-tight door the diameter of which would be designed to fit the diameter of the crew module, so that when the large pressure-tight door of the shield module is opened, this will allow to push the crew module inside the shield module where it can be stabilised by tethering.



50. Astronaut Bruce McCandless II on a spacewalk from Challenger Orbiter (Credit: NASA)

Once the crew module has been fixed in the shield module, the large pressure-tight door of the shield module would be closed, and then, on account of its double-walled design, the pressure-tight door would also be filled with dilatant liquid to provide protection against micrometeorites. Nonetheless, this pressure-tight door would be the weakest point of the shield module, and therefore, the pressurised area between the pressure-tight door of the shield module and the crew module tethered inside the shield module would primarily serve as a cargo hold for the astronauts, which, through the reserves placed therein, would further increase the protection against cosmic ray and micrometeorites.

The cylindrical shield module, on the side opposing the large pressure-tight door, would be provided with an airlock with reinforced structure, which would extend several metres inside the shield module. Once this airlock is installed inside the shield module, the crew module, having an airlock at both ends, would be connected to this airlock with reinforced structure, allowing the astronauts to leave the space habitat module by passing through the airlock of the crew module and the shield module. The airlock of the shield module, beyond the pressure chamber, would also have a room for putting on, removing and storing the spacesuits.



51. Goldstone Deep Space Communications Complex (Credit: NASA)

The minimum three metres between the inner wall of the shield module and the outer wall of the crew module would not only be intended to increase the habitat of the astronauts, but also to provide space for the astronauts for the continuous and large-volume cultivation of fungi like *Cryptococcus neoformans*.

Namely, the amount of dilatant liquid in the inner protective layer of the shield module might be sufficient for protection against micrometeorites, but this half-metres-thick protective layer might not be enough to decrease cosmic ray to a sufficient level and to provide adequate protection against a solar flare – particularly because continuous cosmic ray would eventually render the protective layers to become radioactive, creating a secondary source of radiation –, making it necessary to cultivate fungi on the entire inner surface area of the shield module, as these fungi are able to absorb ionising radiation through melanin, and would therefore further decrease the level of radiation afflicting the astronauts and damaging their living tissue.

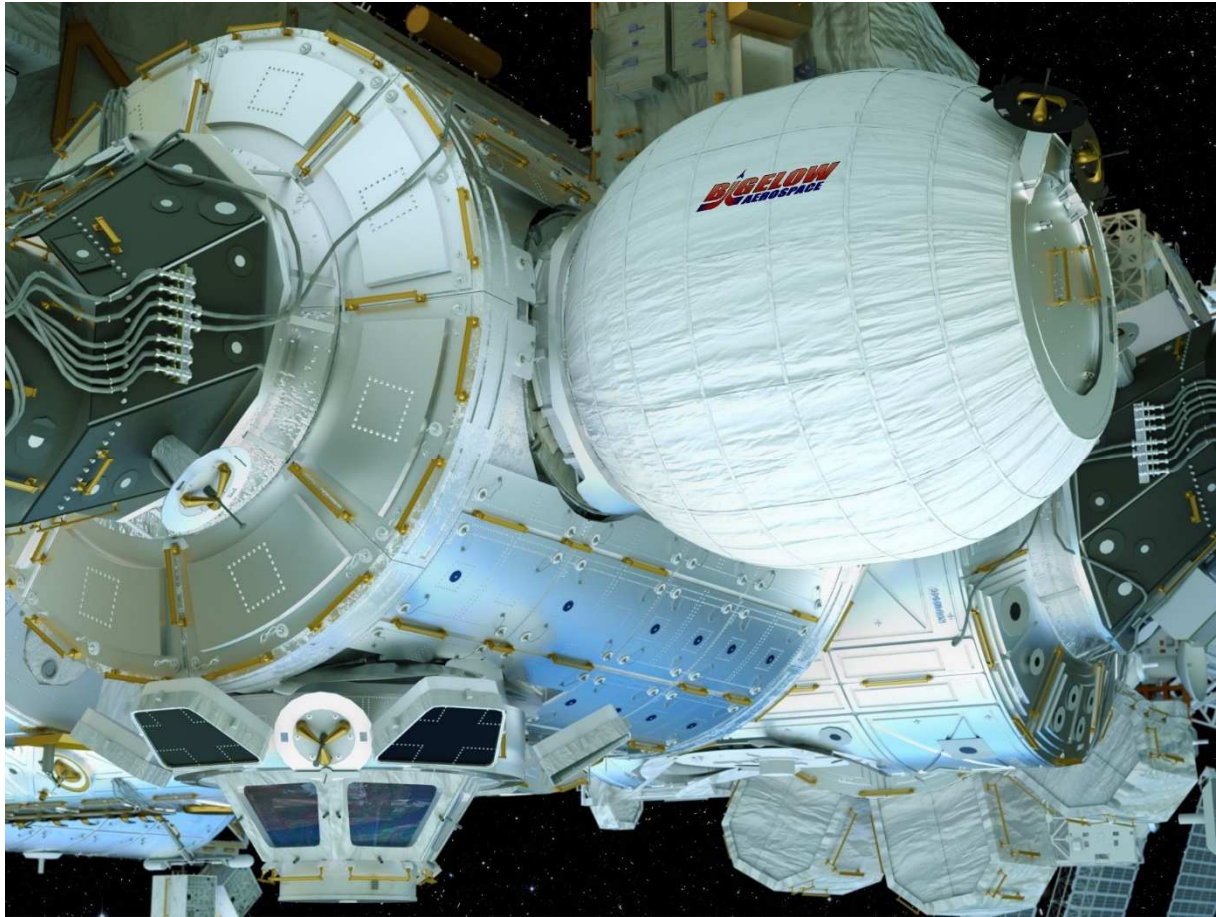


52. A source of cosmic ray, Crab Nebula (Credit: NASA)

The shield module, beyond protection against micrometeorites and cosmic ray, would also be responsible for the primary temperature control of the entire space habitat module. For this, the shield module would be equipped with a high-performance cooling and heating device connected to both protective layers of the shield module as well as to the pressurised inner space extending the

habitat of the astronauts, constantly maintaining the optimal temperature of the high-pressure nitrogen gas in the outer protective layer, of the dilatant liquid in the inner protective layer, as well as of the air in the inner habitat.

With that, the crew module with an autonomous inner temperature control would also be surrounded by three thick, separately controlled and thermally insulated layers, providing significant extra safety throughout deep space missions.



53. Bigelow Expandable Activity Module connected to ISS (Artist's Concept) (Credit: Bigelow Aerospace)

As the crew module would be in a pressurised space inside the shield module, it would be sufficient for the astronauts to use only the shield module airlock throughout deep space missions, and this might seemingly render airlocks to be installed at both ends of the crew module unnecessary, but beyond micrometeorite impacts and occasional fires, countless emergencies may occur that might make the existence of the crew module's own airlocks essential.

An example for the latter: since the separate life-supporting space station module's own protection against cosmic ray and micrometeorites would be minimal as the dimensions of the shield module would only allow placing the crew module inside, and since full reserves should be maintained throughout the Mars mission, another, exactly identical crew module and life-supporting space station module would be connected to the opposing side of the outer rim of the gravity ring, but this reserve crew module would not be provided with a shield module.

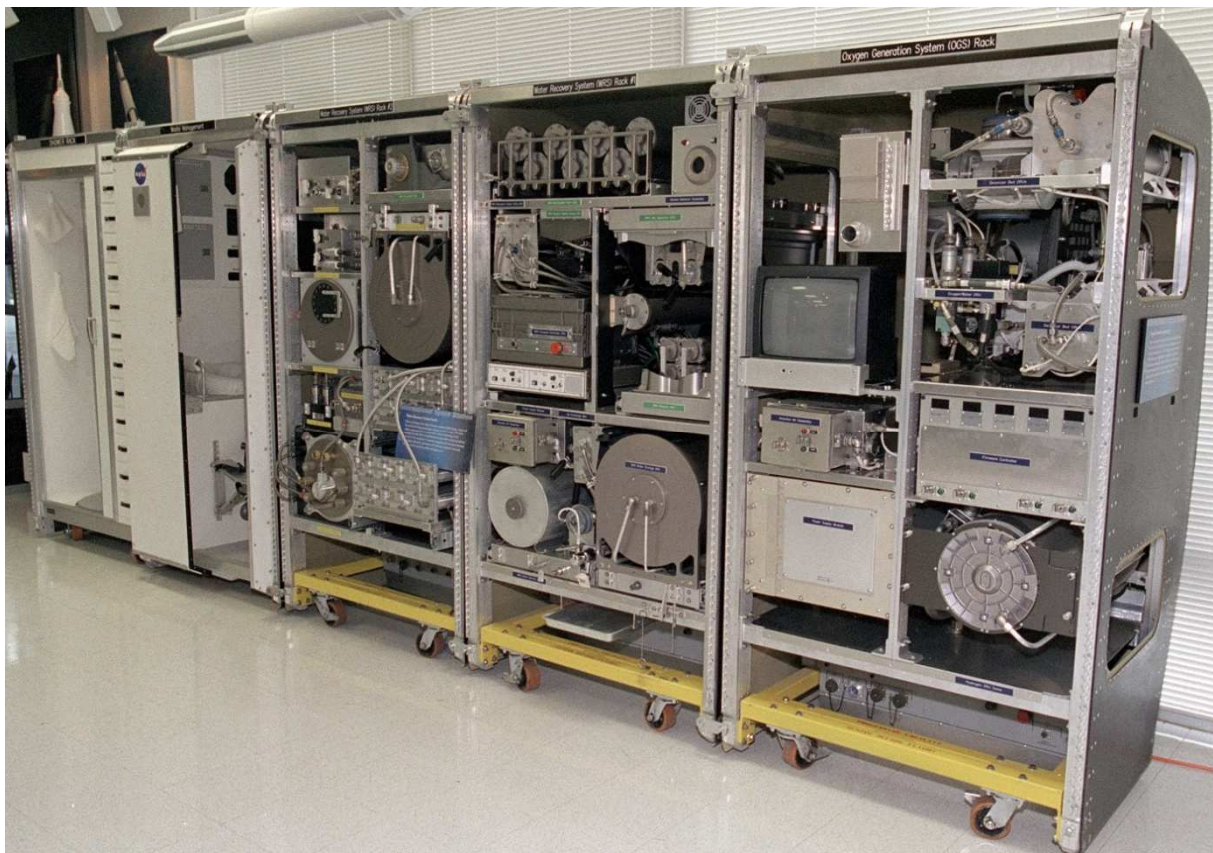


54. Astronaut Nick Hague on a spacewalk at the International Space Station (Credit: NASA)

2.5 Life-Supporting Space Station Module

The life-supporting space station module, connected to the space habitat module fixed to the outer rim of the gravity ring, would have a universal role. While the crew module would have also the most fundamental features, the capabilities of its own life-supporting devices would only be sufficient for emergency use, and therefore, it would be the life-supporting space station module to serve the astronauts in this regard throughout the entire duration of the Mars mission.

The life-supporting space station module would provide the astronauts with drinking water, heating, oxygen, ensure air dehumidifying, optimal air composition by extracting carbon dioxide, constant power supply from the solar panels on the gravity ring, emergency power supply from batteries and from the fuel cells using hydrogen and oxygen, waste management, waste water management, and, among others, water recycling.



55. Environmental Control and Life Support System (Credit: NASA)

The life-supporting space station module would be connected to the outer rim of the gravity ring through a T-shaped connector at the end of a spoke of the gravity ring, allowing the life-supporting space station module to access the several hundred tonnes of hydrogen and oxygen stored in the cryogenic tanks of the gravity ring in liquid state through this T-shaped connector.

As the connectors between the cryogenic tanks of the gravity ring would also provide power- and data network, the life-supporting space station module and the connected space habitat module would also become part of these networks through the T-shaped connector. In order to prevent the life-supporting space station module from hindering the operation of the manoeuvring engine module also connected to the T-shaped connector, the four manoeuvring engine modules of the

gravity ring would not be connected to the edge of the gravity ring facing outwards, but sideways, so that one out of the first two oppositely placed manoeuvring engine modules and the other one out of the second two oppositely placed manoeuvring engine modules would be fixed sideways.

The life-supporting space station module would be connected to the space habitat module – providing the habitat of the astronauts throughout the entire deep space mission – through the reinforced airlock of the shield module, but the life-supporting space station module, similarly to the crew module, would also have its own airlocks at both ends.



56. ECLSS Internal Thermal Control System testing facility at Marshall Space Flight Center (Credit: NASA)

With this, the inner space of the life-supporting space station module, despite practically consisting only of mechanical equipment, batteries, cryogenic tanks, water tanks and air tanks of different storage capacities, would also be a pressurised space filled with air. However, for safety reasons, the astronauts would only be allowed to enter the life-supporting space station module in Starman spacesuits due to the module's negligible protection against micrometeorites and cosmic ray.

Since the life-supporting space station module would form a different angle than the space habitat module due to the polygonal shape of the outer rim of the gravity ring, the long, cylindrical life-supporting space station module would also be provided with a coupling piece of a few square metres at its end towards the space habitat module; this coupling piece could compensate for the difference of a few degrees between the life-supporting space station module and the space habitat

module. This coupling piece would also provide the connection between the equipment of the space station module and the crew module through different pipelines and wires.

The other airlock – at the end of the life-supporting space station module opposite from that of the space habitat module – would also be provided with a universal docking port, allowing docking for any spacecrafts or Mars landers; astronauts would not only be able to leave for the currently docking spacecraft through this airlock, but also for space to go on spacewalks. It would be enough for astronauts to wear Starman spacesuits when transferring to the spacecraft docking currently at the life-supporting space station module or when staying in the life-supporting space station module e.g. for maintenance purposes, however, for the spacewalks, the astronauts would wear xEMU spacesuits developed specifically for working in deep space.



57. Canadarm2 robotic arm at the International Space Station (Credit: NASA)

The life-supporting space station module would also be provided with a Canadarm robotic arm; beyond its basic purpose of aiding the docking of spacecrafts, the length of this robotic arm would allow reaching any point of the outer casing of both the life-supporting space station module and the space habitat module using the robotic arm. Beyond the regular examination of the outer casing, this would also aid the astronauts in the easier restoration of any casing damages caused by micrometeorites.



58. *Helix Nebula (Credit: NASA)*

2.6 Technical Service Spacecraft

The gravity ring alone – which could also be used as a deep-space spacecraft – could easily serve a Mars mission, which may take up to two years, but since the gravity ring must always show the same, solar-panel-covered side towards the Sun while moving in deep space in order to keep the cryogenic tanks storing liquid hydrogen and oxygen in shade constantly, not to mention the fact that any manoeuvring with the gravity ring of a diameter of 200 metres would consume a tremendous amount of rocket fuel, once the gravity ring leaves low Earth orbit, it would merely be considered a moving space station.

A technical service spacecraft would therefore be developed within the framework of Phoenix Program, allowing the astronauts to move away from the gravity ring beyond the range of the Manned Manoeuvring Unit (MMU) connected to their spacesuits if necessary, and also allowing them to grasp, remove and replace space station modules of different purposes along the edge of the gravity ring in deep space, tens of millions of kilometres from the Earth.

An example for the latter is when the life-supporting space station module connected to the space habitat module must be replaced with the reserve life-supporting space station module fixed to the opposite side of the gravity ring due to a non-repairable damage or defect.



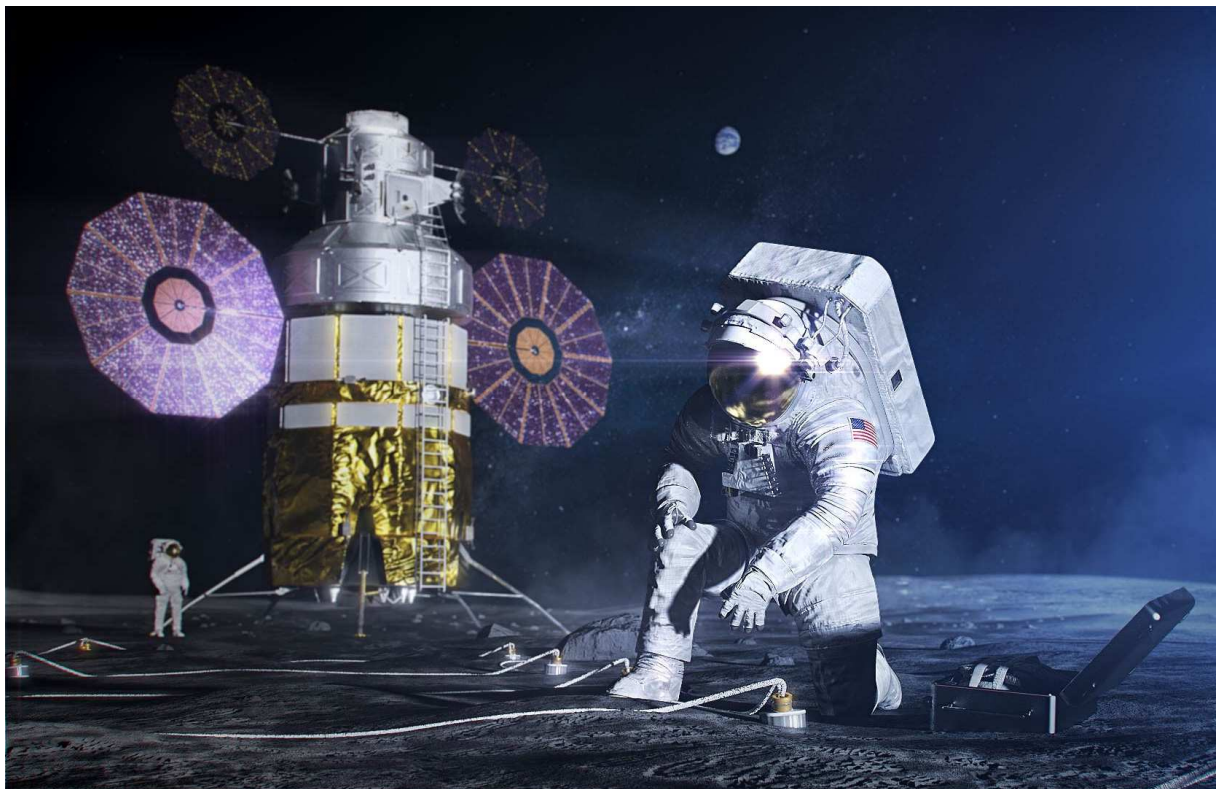
59. Orion Multi-Purpose Crew Vehicle with ATV service module (Artist's Concept) (Credit: ESA)

The technical service spacecraft would be developed on the basis of Orion MPCV, but would have fundamental differences. For instance, the technical service spacecraft would not be provided with a heat shield, and unlike Orion MPCV, its service module would have the same diameter as the crew module, and the two would be incorporated completely. The service module would not be provided with foldable solar panels either, instead, the solar panels would be located on the casing of the

service module – similarly to SpaceX Dragon 2 spacecraft – in order to avoid hindering manoeuvres in the close proximity of the gravity ring.

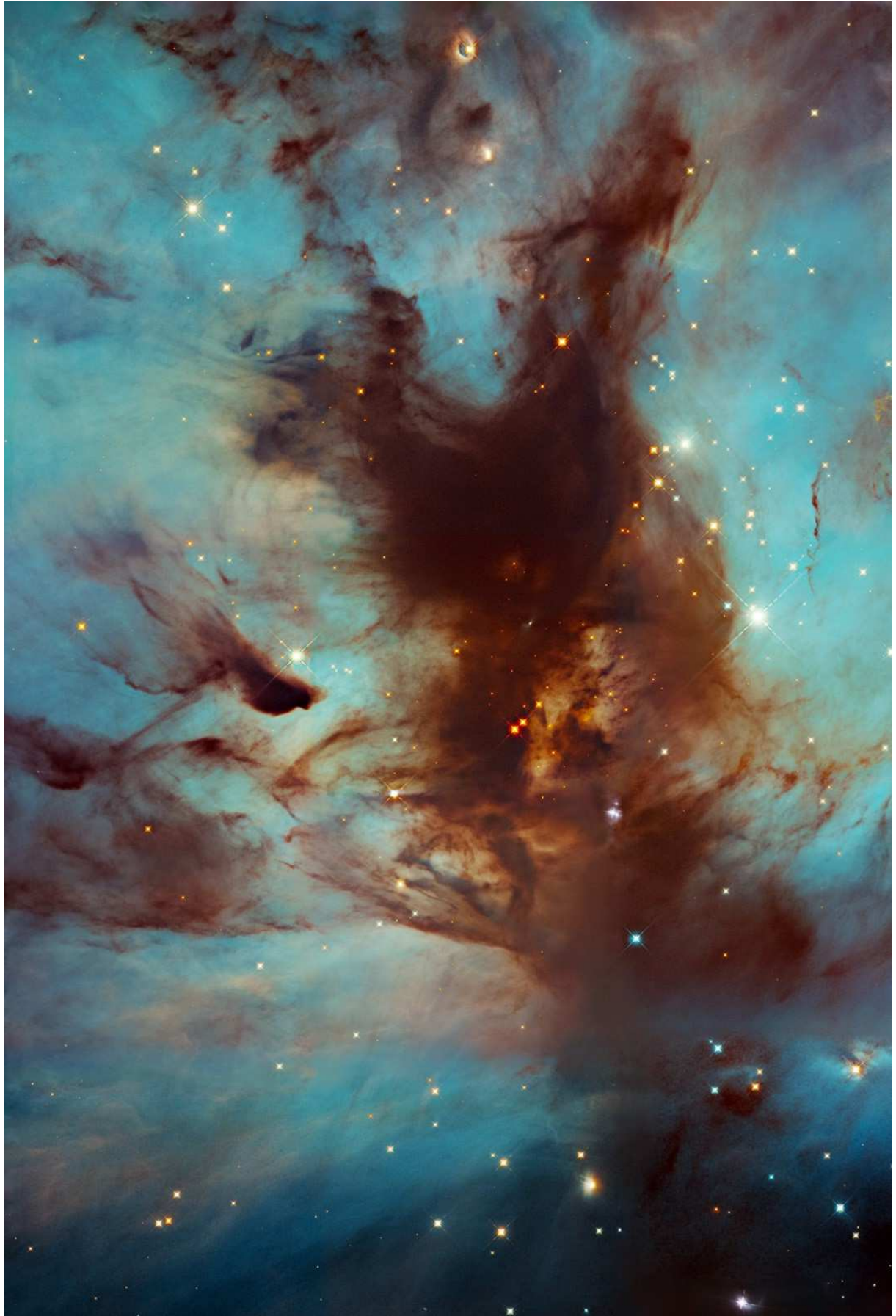
The docking port on the nose of the technical service spacecraft would be positioned frontwards – unlike in the case of Orion MPCV –, as the technical service spacecraft would also be provided with a smaller airlock – unlike Orion MPCV yet again. This cylindrical airlock would be custom-designed, as there would be four pressure-tight doors on the outer casing to be opened and closed separately, and each would be fitted with an xEMU spacesuit connected through the openings on their backs, so that the large xEMU spacesuits positioned by angles of 90 degrees on the outer casing of the airlock of the technical service spacecraft would not interfere with the operation of the manoeuvring nozzles of the crew module.

Since xEMU spacesuits – developed by NASA specifically for working in deep space – do not have to be put on piece-by-piece, and astronauts can equip one by getting in through the opening on the back of the spacesuit, the diameter of the airlock of the technical service spacecraft would not have to be larger than the diameter of the docking port, allowing astronauts to embark on spacewalks fast and simply in their spacesuits which are already in space, which is of particular importance in case of emergency repairs.



60. Astronauts in xEMU spacesuits on the surface of the Moon (Artist's Concept) (Credit: NASA)

Two Canadarm robotic arms would also be installed in the service module of the technical service spacecraft, so that the technical service spacecraft could simultaneously secure itself to the gravity ring with one Canadarm robotic arm and move a space station module or an astronaut performing mechanical works with the other Canadarm robotic arm.



61. Flame Nebula (Credit: NASA)

The technical service spacecraft would be docking at the docking port of the life-supporting space station module connected to the space habitat module of the gravity ring throughout the entire deep space mission. However, a reserve technical service spacecraft would also be available for the Mars mission, which would simply be connected to the outer rim of the gravity ring with consideration to the optimal weight distribution required for the stable rotation of the gravity ring.

Unlike Orion MPCV, the technical service spacecraft would use liquid hydrogen and liquid oxygen as rocket fuel for manoeuvring. It might be easier to have devices for the Mars mission which consume another type of rocket fuel that requires less or no cooling compared to liquid hydrogen and liquid oxygen, but the exclusive use of liquid hydrogen and liquid oxygen would make the key elements of deep space missions – from gravity ring to Mars landers – as compatible with one another as possible, allowing the astronauts to always have sufficient rocket fuel, oxygen and water for solving or at least overcoming issues from micrometeorite impacts to fires caused by malfunctions of the space habitat module, as well as for returning to the Earth under any circumstances.



62. Orion Exploration Flight Test-1 Flight Control Room (Credit: NASA)

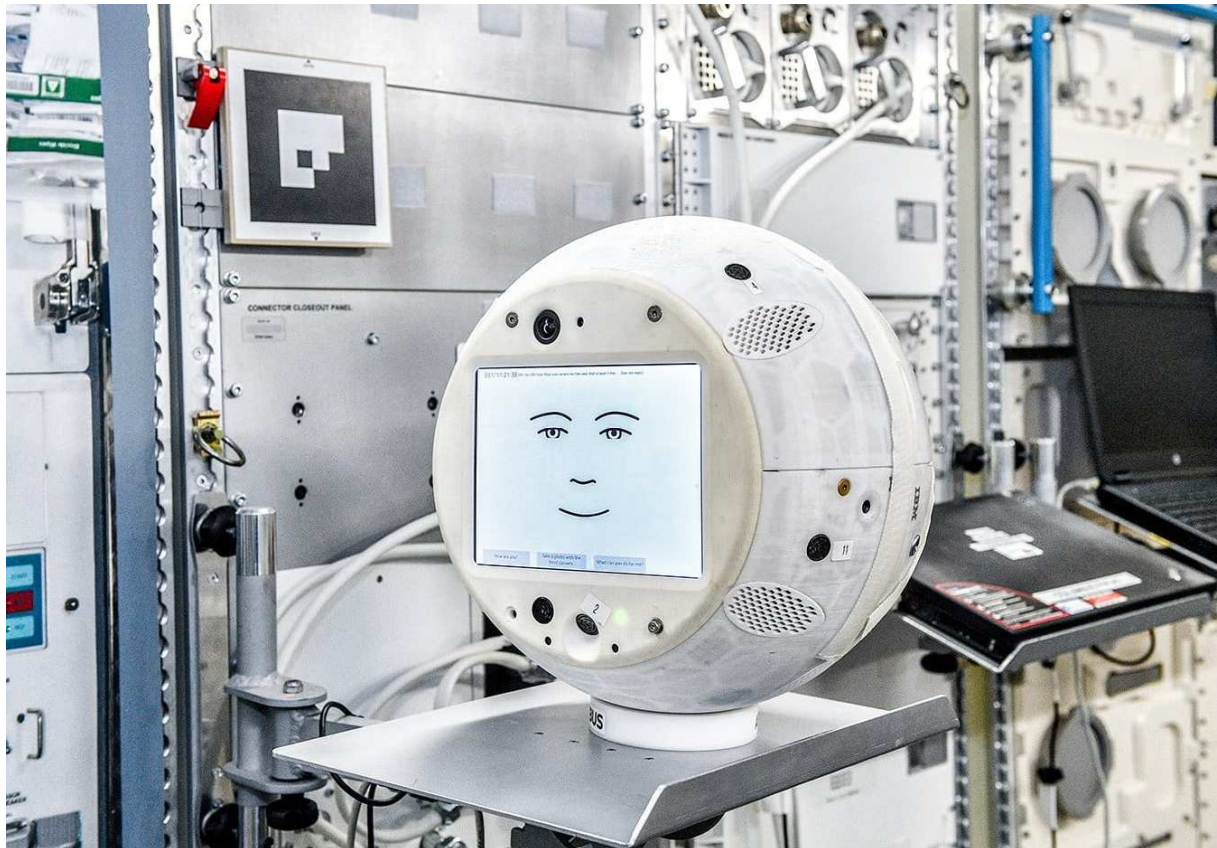
To this end, the universal docking port of the life-supporting space station module – capable of docking any spacecraft or Mars lander – would also be a LOX/LH2 rocket fuel transfer unit, allowing to refuel the currently docking spacecrafts with liquid hydrogen and liquid oxygen, preparing them for different deep space operations or landing on the surface of Mars.

However, large-scale compatibility is not required only for LOX/LH2 rocket fuel and the related cooling equipment, pumps, valves and rocket engines, but also for operating systems and dedicated software used e.g. for the Mars mission. This, in case of an emergency entailing the abortion of a mission – similar to the events of Apollo 13 –, would allow the immediate availability of devices

designed for different purposes, even if it means that the devices have to perform operations completely different from their original purposes in a specific Mars mission.

2.7 Technical Reconnaissance Robot

Throughout a Mars mission, which may take up to two years, the entire structure of the gravity ring, as well as every connected unit, space station module, spacecraft and lander should be monitored constantly, not only with regard to the sensor data of the telemetric systems, which are practically incorporated in everything, but also with regard to searching signs on the outer casing from material fatigue to micrometeorite impacts.



63. Crew Interactive MObile companion (CIMON) (Credit: IBM)

This, however, is not an easy task in case of a constantly rotating gravity ring of a diameter of 200 metres, and to this end, based on the Airbus CIMON robot, an autonomous monitoring device usable in deep space would be designed specifically for this purpose within the framework of Phoenix Program.

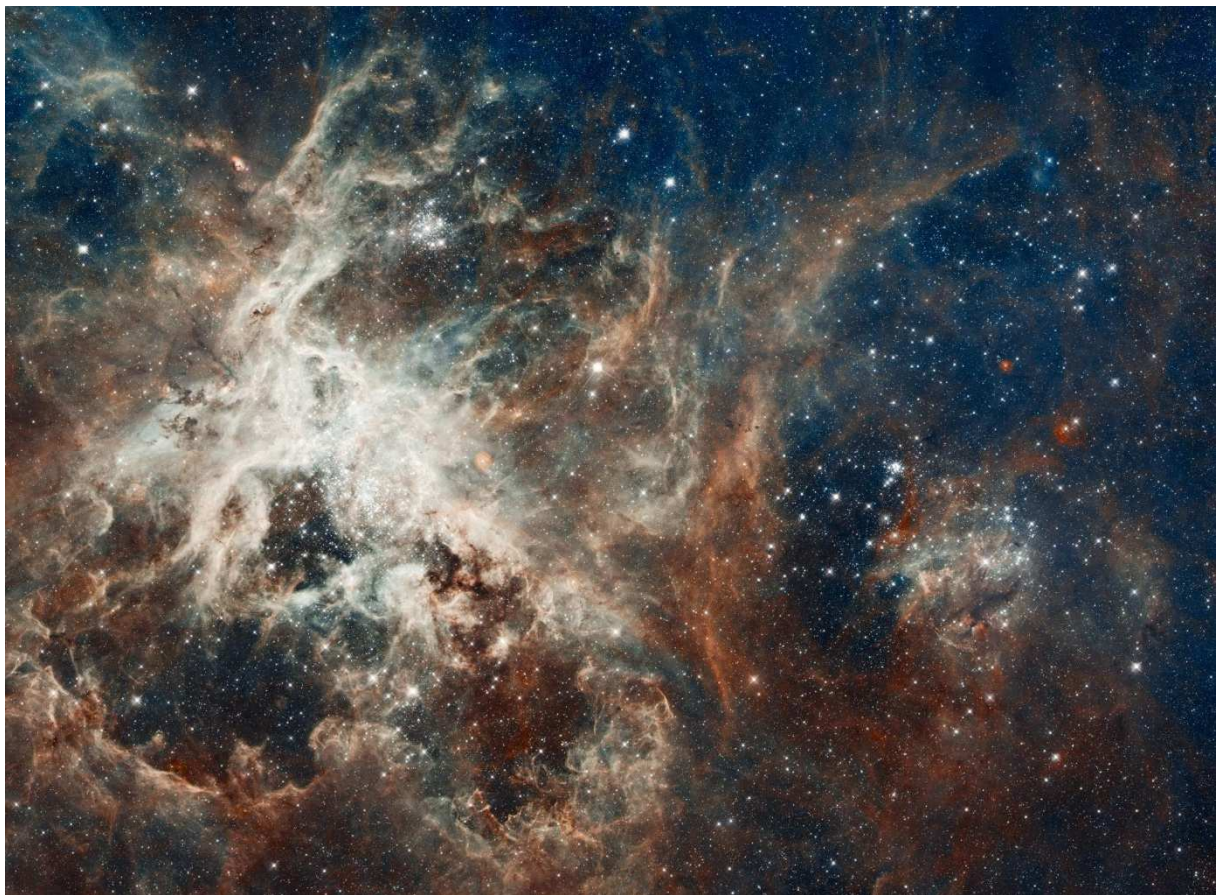
Since this technical reconnaissance robot would always be working in the shade cast by the iROSA solar panels of the gravity ring – with a few exceptions –, it would be unnecessary to have its own solar panels. As a result, however, this spherical technical reconnaissance robot would have a minimum diameter of 1 metre in order to ensure a battery capacity sufficient for several days of uninterrupted operation in space, supplying its own optical devices, on-board computer, communications equipment and cooling equipment protecting its circuits.



64. Witch Head Nebula (Credit: NASA)

The astronauts will produce a great deal of carbon dioxide in the space habitat module with their breathing throughout a Mars mission, which may take up to two years; a part of this carbon dioxide could be converted back to oxygen with a device based on NASA MOXIE, which would use the power produced by the iROSA solar panels of the gravity ring, while the so-produced carbon monoxide would be an ideal propellant for the technical reconnaissance robot.

The spherical technical reconnaissance robot could easily navigate in the immediate environment of the gravity ring by swiftly releasing the carbon monoxide – stored in gaseous state in a high-pressure tank – through the manoeuvring nozzles, and making high-resolution images of almost every square centimetre of the gravity ring would allow ground mission control centre to perform a continuous assessment of the structure of the gravity ring by photo analysis.



65. Tarantula Nebula (Credit: NASA)

The technical reconnaissance robot would be provided with artificial intelligence, making it a largely autonomous device, which would prevent the astronauts from losing time on the real-time remote controlling of the technical reconnaissance robot, which the ground mission control centre would not be able to perform either due to time lag caused by the great distance in communications.

There would be several of these technical reconnaissance robots available for the Mars mission as a reserve, and the outer casing of the life-supporting space station module of the gravity ring would also be equipped with a smaller docking port designed specifically for supplying these technical reconnaissance robots; this port would allow recharging and refuelling the currently used technical reconnaissance robot with power and carbon monoxide respectively, without the need for

astronauts to bring the robot into the pressurised inner space through the airlock of the life-supporting space station module.

To avoid the irrevocable loss of tools fixed incorrectly and lost accidentally by astronauts during reparations requiring spacewalks, the technical reconnaissance robot would also be provided with a small robotic arm, allowing the collection of accidentally lost tools and objects. This hinged robotic arm would be located inside the technical reconnaissance robot by default in order to avoid ruining the perfect spherical shape of the robot.

The existence of this small robotic arm would also allow the technical reconnaissance robot to fix itself firmly anywhere on the gravity ring, so that the technical reconnaissance robot could minimise the consumption of carbon monoxide in case a specific location, e.g. a leaking cryogenic tank should be monitored for several days.



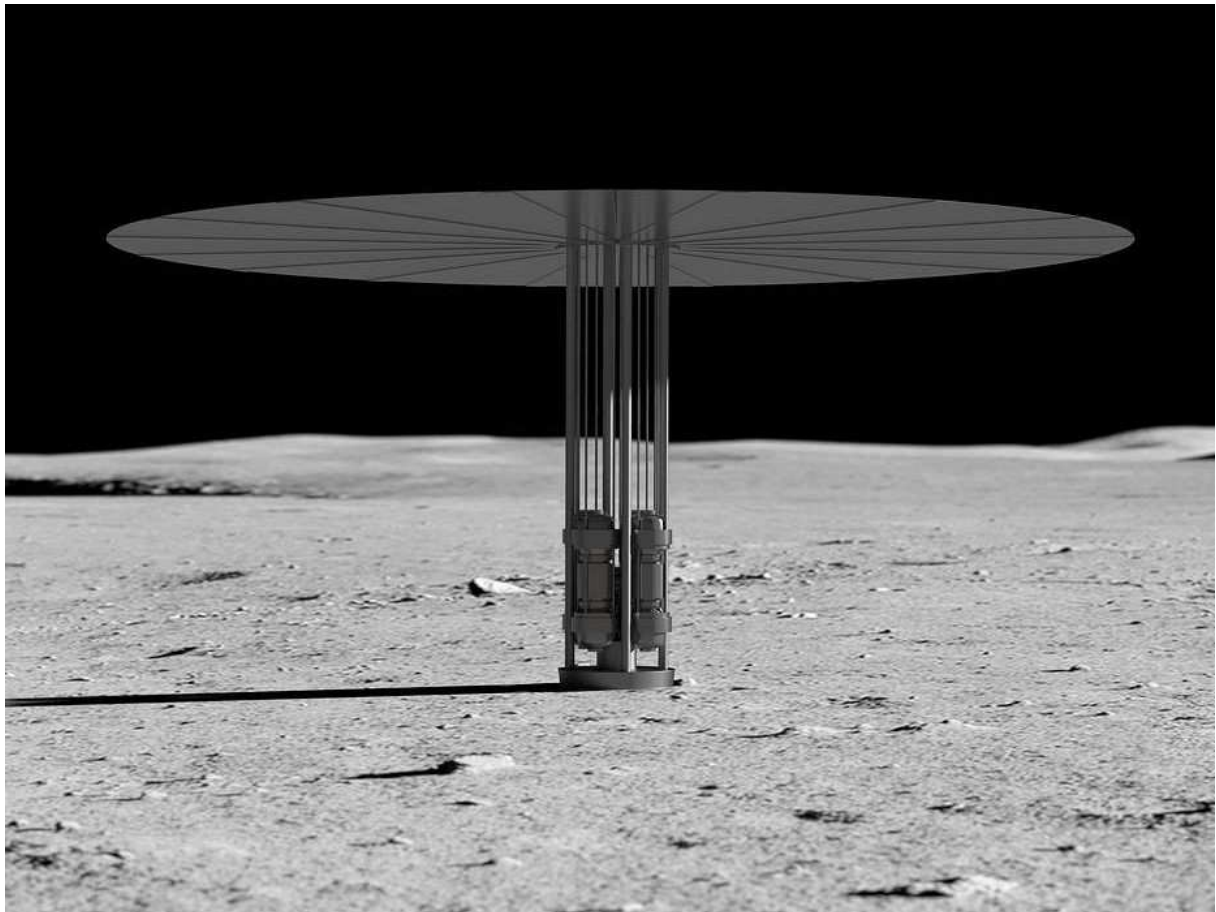
66. Astronaut Mark C. Lee testing the Simplified Aid for EVA Rescue (SAFER) system (Credit: NASA)

The spherical technical reconnaissance robot would be provided with at least a dozen of heavy-duty handrails distributed evenly on its outer casing. In case of an emergency, when the safety tether of a spacewalking astronaut were to be cut for any reason and render them unable to control their movements, the technical reconnaissance robot would manoeuvre immediately to the astronaut, the astronaut could grab the handrails, use the manoeuvring nozzles to stabilise themselves with simple voice commands, and return automatically to the gravity ring or to the technical service spacecraft.

2.8 Using Nuclear Energy

Complex structures, such as deep-space spacecrafts, are equipped with many sensors in every part, allowing the constant monitoring of everything, from the inspection of the proper closing of valves, to measuring forces endangering structural stability, to checking the level of carbon dioxide in the air of pressurised habitats. In many cases, however, it is impossible to connect these sensors to the energy network of deep-space spacecrafts, which may largely limit their usability due to the energy demands of such sensors throughout a deep space mission, which may take up to two years.

However, the combination thereof with the technology trapping the coal isotope of mass number 14 in synthetic diamonds would allow placing sensors of all kinds anywhere on the gravity ring, as the so-manufactured Nano Diamond Batteries (NDB) could constantly supply these sensors and the related wireless data-transferring communication equipment with energy, without the risk of discharging completely.



67. Kilopower fission reactor on the surface of the Moon (Artist's Concept) (Credit: NASA)

The iROSA solar panels placed on the gravity ring of a diameter of 200 metres could cover the full energy demand of the Mars mission without any difficulties, but when planning a deep space mission, which may take up to two years, no chances should be taken, and steps should be taken to prepare for all eventualities. With that in mind, a reliable nuclear power generation could significantly reduce the risks of the Mars mission, which is why nuclear reactors of different performance rates developed within the framework of Kilopower Project by NASA would play a pivotal role in Phoenix Program.



68. Lagoon Nebula (Credit: NASA)

Since the space habitat module fixed to the edge of the gravity ring and providing habitat for the astronauts would be protected well against cosmic ray, power generation with a nuclear reactor would pose a minimal risk to the health of the astronauts, and in case this nuclear reactor would be connected to the outer rim of the gravity ring on the exact opposite side than the space habitat module, the entire structure of the gravity ring between the space habitat module and the nuclear reactor with the gravity ring's diameter of 200 metres and the several hundred tonnes of LOX/LH2 rocket fuel stored inside would shield against radiation.

If the relevant NASA developments are completed, the significant protection of the space habitat module of the astronauts against radiation would also provide an opportunity to connect a Nuclear Thermal Propulsion (NTP) rocket engine to the gravity ring as well – beyond the traditional chemical propulsion rocket engine of the course correction engine module connected to the central structural element of the gravity ring.



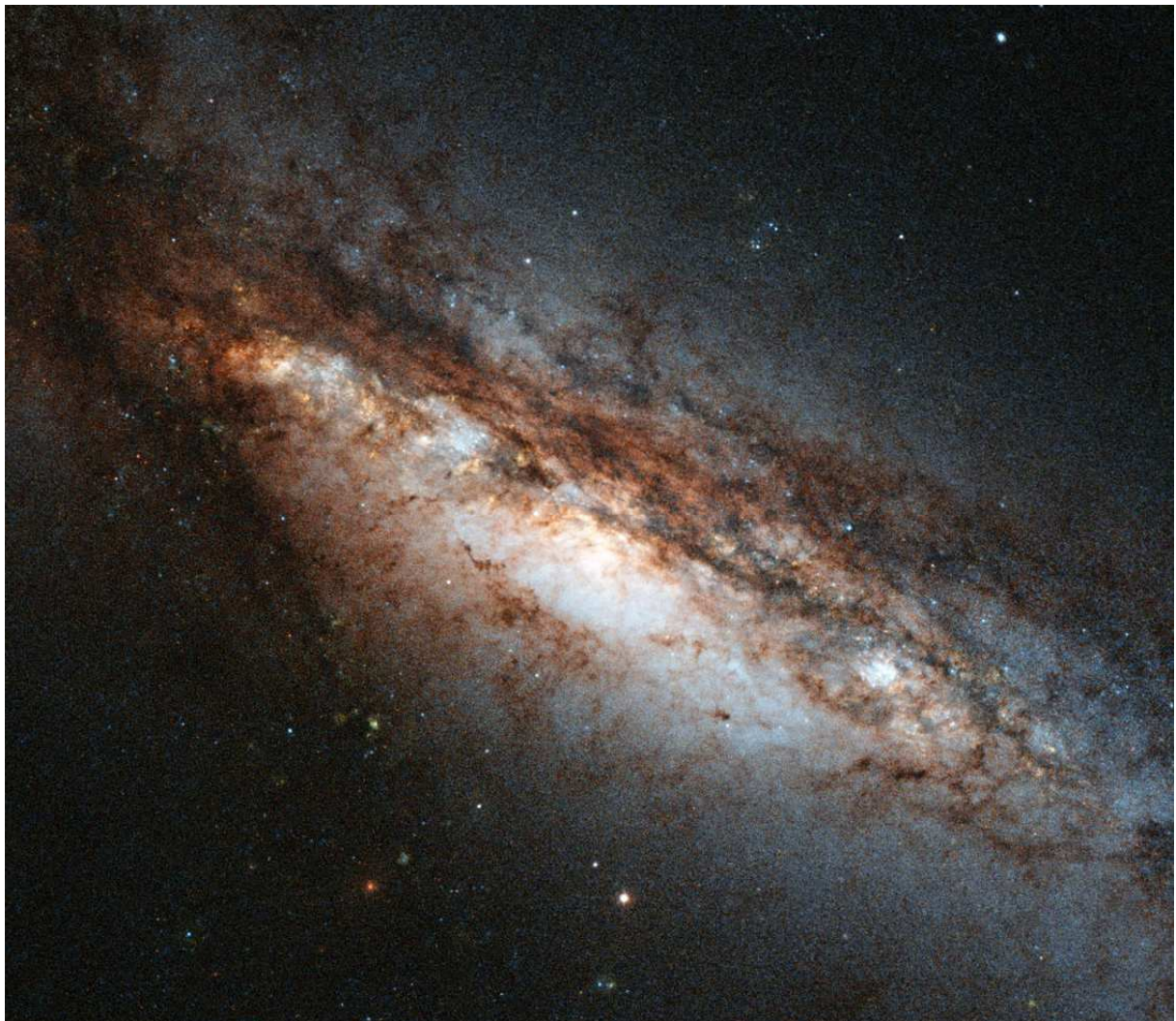
69. Deep-space spacecraft with Nuclear Thermal Propulsion (Artist's Concept) (Credit: NASA)

The NTP engine module to be developed within the framework of Phoenix Program would be connected to the cryogenic space station module of the gravity ring after the construction of the gravity ring is completed and the gravity ring is detached from the International Space Station. With that, the course correction engine module and the NTP engine module would be located on two opposing sides of the gravity ring.

The NTP engine module and the cryogenic space station module would thereafter constitute one structural unit, as the cryogenic space station module would not only supply the NTP engine module with liquid hydrogen propellant to generate thrust, but the cryogenic space station module would also provide continuous cooling for the reactor of the NTP engine module when rocket propulsion provided by the NTP engine module is not needed.

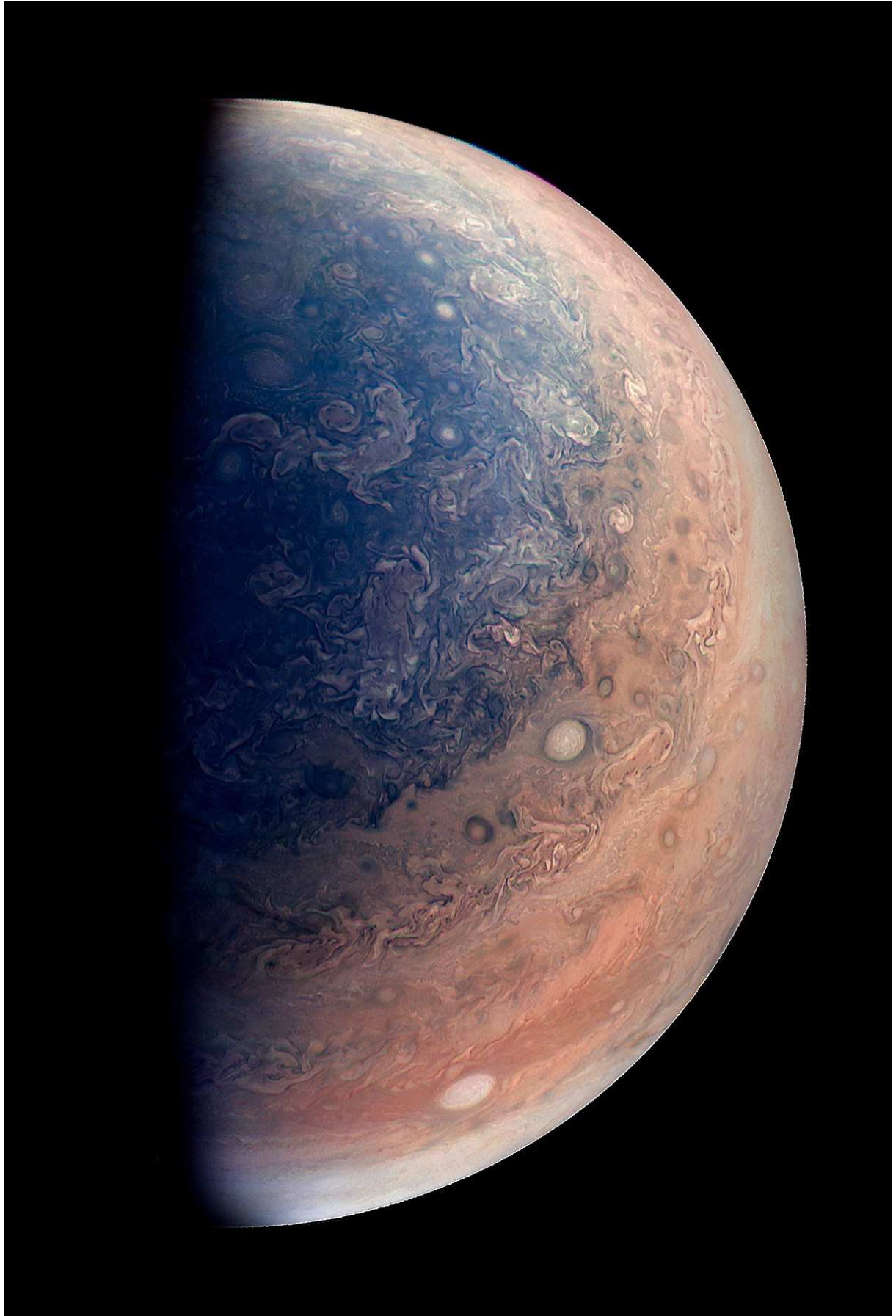
The reactor would be cooled with the liquefied helium stored in large volumes in the cryogenic space station module, and the coolant circuit of the reactor of the NTP engine module would use the excess heat for energy production before transferring towards the heat emitter radiators, allowing the NTP engine module of the gravity ring to operate in two operating modes, in rocket propulsion mode or in energy production mode.

For safety reasons, the NTP engine module would also be equipped with a solid-propellant launch escape system, which could move the NTP engine module to a long distance from the gravity ring within a few seconds in case a malfunction of the reactor would pose a danger to the astronauts. This emergency ejection system could not only be actuated manually by the astronauts, but also completely automatically when specific critical heat or, among others, radiation threshold levels are reached.



70. NGC 660 polar-ring galaxy (Credit: NASA)

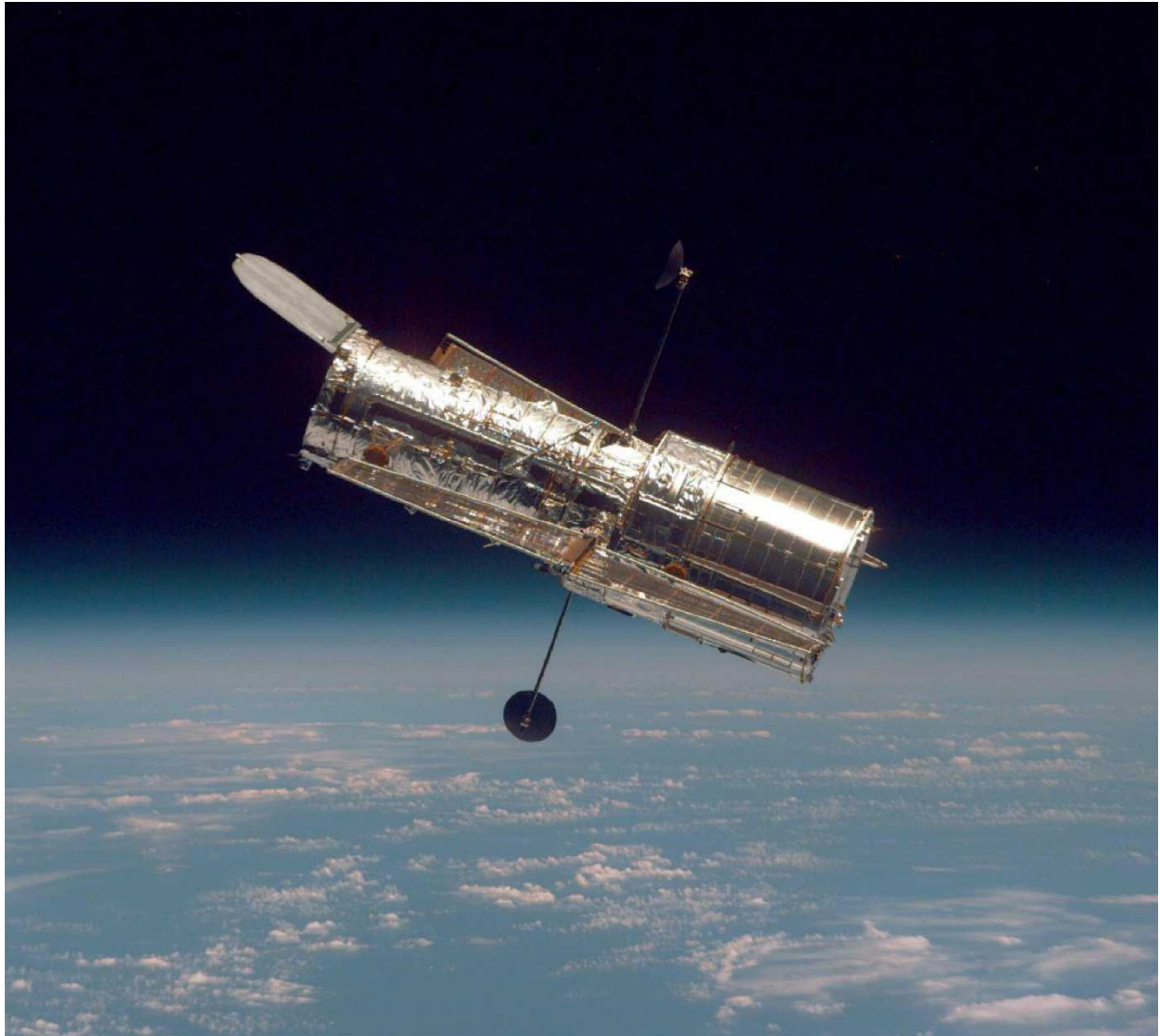
Since the combustion time of the solid-propellant launch escape system would only be a few seconds, the astronauts could easily get to the NTP engine module moved away from the gravity ring in case it can still be saved on the basis of the reasons of the malfunction, and could still tow it back to the gravity ring after repairs are completed.



71. Jupiter's south pole (Credit: Gabriel Fiset)

2.9 Deep Space Observatory

The role of space exploration in the history of mankind is so much more than planting a flag on another planet. Countless scientific programmes facilitate human development, from understanding the creation of the universe, to climate research and weather forecasting, to searching for life on other planets. And the gravity ring could be used as a platform for scientific programmes of all kinds beyond serving the Mars mission.



72. Hubble Space Telescope (Credit: NASA)

Since the gravity ring could provide a safe habitat for astronauts in deep space by the artificial gravity maintained through its rotation and by the sufficient radiation protection of its space habitat module, thanks to maintenance and reparation opportunities by the continuous presence of the astronauts, it would be easier to perform scientific programmes on the gravity ring for which low Earth orbit is not ideal.

One such opportunity is to use the gravity ring as a deep space observatory by connecting the fairly olden Hubble Space Telescope to the gravity ring. Since the space habitat module of the astronauts would be a windowless, completely closed structure, and the rocket engines of the gravity ring would

not be used except for major course corrections, Hubble Space Telescope could be fixed to the gravity ring, allowing the space telescope to look for asteroids threatening the Earth and also to examine galaxies far away, without any disturbing light pollution in the shade of the iROSA solar panels.

Since Hubble Space Telescope is at a little bit higher altitude than the International Space Station, but still on low Earth orbit, the space telescope could be fixed to the structure of the gravity ring during the construction thereof on account of its easy accessibility, by using a robotic arm similar to Canadarm, capable of rotation in almost every direction. The opportunity of fixing Hubble Space Telescope to the gravity ring and positioning that with a robotic arm would also allow setting the space telescope at the sectors to be observed quickly, with a high accuracy and without consuming any propellant.

Once the gravity ring is set in orbit around Mars, Hubble Space Telescope – with high-performance stereo radar equipment – could be used to prepare a three-dimensional map of the entire planet accurate to the nearest centimetre, which would make it easier to plan current and future missions on the Mars surface.



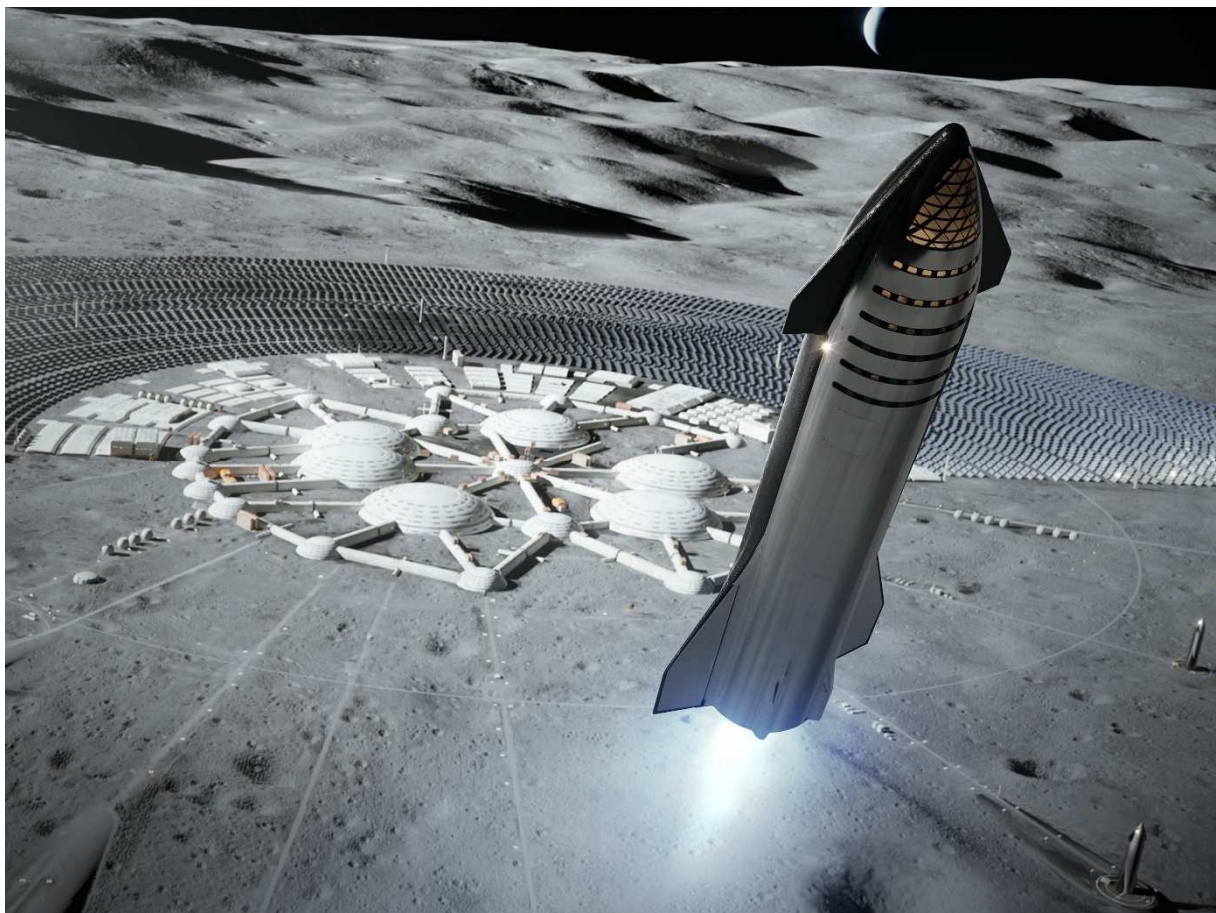
73. Astronauts during Hubble Space Telescope servicing mission (Artist's Concept) (Credit: Paul Hudson)

Chapter 3: Landers

Countless different landers are needed to land on Mars, to establish the Mars base, to perform scientific tasks and to launch from Mars, however, to avoid several decades of development, the landers should be built on the same basis similarly to motor vehicle industry, where completely different models can be built on the same chassis due to the modular structure.

On account of the compatibility of components and control mechanics, landers built on the same basis are safer than landers developed separately on the basis of specific tasks, since this makes it easier for astronauts to find and fix issues both in deep space and on the surface of Mars.

The SpaceX Starship super heavy booster offers considerable potential for manned space exploration thanks to its full reusability, extraordinary carrying capacity and low launch costs, however, its second stage Starship spacecraft would not be used in Phoenix Program as its Mars version would not provide sufficient safety.



74. SpaceX Starship spaceship (Artist's Concept) (Credit: SpaceX)

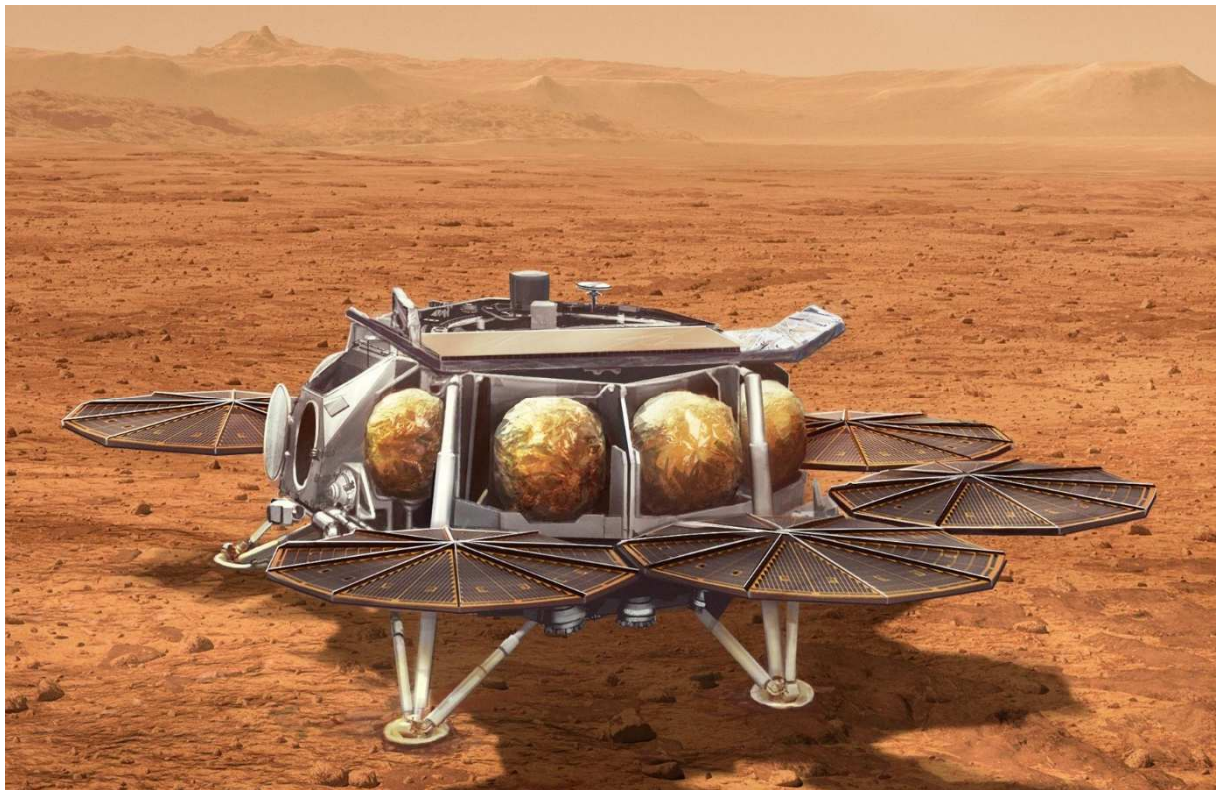
The risk is posed by the heat-shield panels known well from the disaster of Columbia spaceplane, and while this risk is tolerable for lunar missions and for ordinary missions around the Earth, it is not tolerable for a Mars mission, which may take up to two years, and consume substantial financial sources, and therefore, the landers of Phoenix Program would be designed as space capsules, which is much simpler and safer.



75. A base on Mars (Artist's Concept) (Credit: John J. Olson)

Five lander categories would be developed within the framework of Phoenix Program: an exploration vehicle to inspect the vicinity of the Mars base, a Mars shuttle to send the astronauts down to the surface of Mars and to bring them back, a nuclear supply module supplying energy to the Mars base and oxygen to the astronauts, a propellant shuttle providing liquid hydrogen and liquid oxygen supply allowing the Mars shuttle to launch, and finally, base modules for establishing the habitat on the Mars base, which would be optimised for different tasks, but would have the same construction.

The landers would be set on low Earth orbit with SpaceX Falcon Heavy launch vehicles, where the landers would be connected to the outer rim of the gravity ring according to the optimal weight distribution of the gravity ring. Since all the LOX/LH2 rocket fuel required for the Mars mission would be delivered to the gravity ring by the reusable propellant carrier spaceplanes of Phoenix Program, it would be sufficient for Mars landers to have a minimum amount of rocket fuel upon launch, enough just to manoeuvre on low Earth orbit and to reach the gravity ring.



76. Mars Sample Retrieval Lander (Credit: NASA)

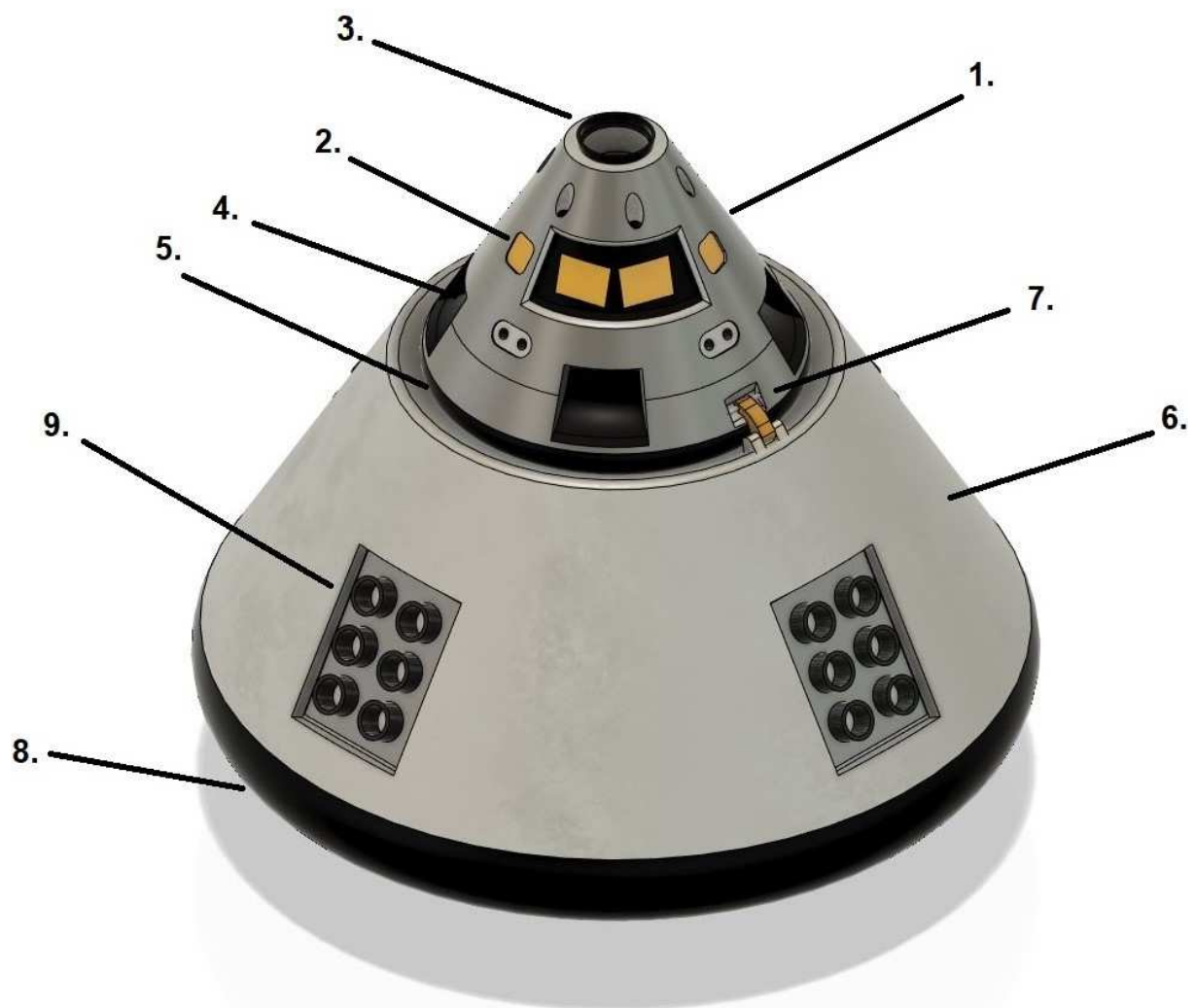
As SpaceX Falcon Heavy launch vehicle can carry more than 60 tonnes of payload to low Earth orbit, and since the landers can be launched to space with quasi empty propellant tanks, it is possible to design the landers to have a diameter more than double of the traditional five metres, which is crucial both for aerodynamic braking in the thin Martian atmosphere and for the amount of payload to be sent down to the surface of Mars.

All categories of Mars landers would use liquid hydrogen and liquid oxygen rocket fuels both in the main and in the manoeuvring rocket engines. At the same time, on account of the large volumes of hydrogen and oxygen available, the landers' own primary power supply could be fuel cells using gaseous hydrogen and oxygen, which, as a by-product, produces another crucial resource: water.

In order to be prepared for different emergencies, each lander as well as the technical service spacecraft of Phoenix Program would be provided with two resource-distribution connectors on the outer casing. These universal connectors would allow landers on the surface of Mars to be connected to one another through flexible, multi-purpose charging cables in order to share or redistribute available resources.

Through the resource-distribution connectors, these flexible charging cables would allow establishing power- and data link, sharing water resources, as well as pumping both gaseous and liquefied hydrogen and oxygen in any direction among the landers.

3.1 Structure and Operation of the Mars Shuttle



77. The Mars shuttle (simplified illustration; not to scale) (Designed by with additional ideas: Roland Gadár)

1. Crew module. The Mars shuttle would consist of two main parts, the top part of which would be a redesigned version of the crew module of Orion MPCV.

2. Windows. Even though the Mars shuttle, based on Orion MPCV, would have its crew module redesigned considerably, it would still be considered a fully operational spacecraft, and might be used for purposes completely different from its original function in case of an emergency.

3. Docking port. Similarly to the docking port of the technical service spacecraft, beyond being boarded and left by the astronauts, it would also be suitable for supplying the Mars shuttle with LOX/LH2 rocket fuel, so that the astronauts would not have to connect the Mars shuttle separately to the life-supporting space station module through the resource-distribution connectors once it has docked at the life-supporting space station module of the gravity ring.

4. Rocket engines. Unlike the original Orion MPCV, the crew module of the Mars shuttle would be provided with thrust-controlled LOX/LH2 rocket engines, which could also be restarted several times; however, the thrust of these rocket engines and the amount of rocket fuel to be allocated in the crew module of the Mars shuttle would not be sufficient for the crew module to land on Mars by itself. The crew module of the Mars shuttle would have four LOX/LH2 rocket engines built into its side.

5. Secondary heat shield. Despite the redesign, the crew module of the Mars shuttle would still be provided with a heat shield, which would be the heat shield of Orion MPCV optimised for Martian atmosphere.

6. Service module. The other main part of the Mars shuttle would be its bottom part, that is, the service module, which would require the replacement of the ESM service module used for Orion MPCV, as the service module of the Mars shuttle would have fundamentally different features. Instead of the traditional cylinder shape, the service module of the Mars shuttle would be conical similarly to the crew module, and its tip would be the crew module itself. The service module would be provided with LOX/LH2 rocket engines with a thrust suitable for landing on Mars, as well as with liquid hydrogen and liquid oxygen tanks with a storage capacity sufficient for feeding the rocket engines. The service module would also be equipped with the same robotic legs as NASA ATHLETE, the structure and load-bearing capacity of which would allow to be used as landing gear and also for moving on the surface of Mars, as Mars gravity is only third of Earth gravity. Unlike the original ESM service module, the service module of the Mars shuttle would not be provided with solar panels, instead, it would be provided with a radioisotope thermoelectric generator (RTG) to complement its primary energy producers of hydrogen- and oxygen-fuelled fuel cells. An RTG could produce only a few hundred watts of energy, and its use might pose a significant risk to the astronauts, but this is the only source of power and heat the astronauts could definitely rely on under any circumstances. This could be a critical factor of survival on the dry and cold surface of Mars in case of an emergency, e.g. when the astronauts land the Mars shuttle several hundred kilometres from the other landers due to missing the angle of atmospheric entry or the landing zone.

7. Clamping handles. The crew module and service module of the Mars shuttle would be connected to one another similarly to the original Orion MPCV, however, the clamping handles of the Mars shuttle would be designed for much more workload, as these clamping handles will have to withstand forces resulting from landing on and launching from the surface of Mars.

8. Primary heat shield. Similarly to the crew module, the service module of the Mars shuttle would also have its own heat shield optimised for Martian atmosphere, the diameter of which, on account of the conical shape of the Mars shuttle, would be multiple of the heat shield of the crew module. This primary heat shield would be disposable so that the high-performance LOX/LH2 rocket engines and ATHLETE robotic legs underneath could be used for landing the Mars shuttle.

9. Fixing points for propellant shuttles. There might be a sufficient amount of liquid hydrogen and liquid oxygen in the service module of the Mars shuttle for landing the Mars shuttle safely on the surface of Mars, but it would not be enough for the Mars shuttle to launch from the surface of Mars and reach Mars orbit again. For this reason, propellant shuttles would be connected to the reinforced fixing points of the service module of the Mars shuttle prior to the launch; these propellant shuttles would act as booster rockets and use their own LOX/LH2 rocket engines and cryogenic rocket fuel tanks to aid the Mars shuttle in reaching Mars orbit. The outer casing of the service module of the Mars shuttle would be equipped with fixing points for propellant shuttles by angles of 90 degrees. The Mars shuttle and the connected propellant shuttles, with regard to their dimensions, the main LOX/LH2 rocket engines' performance and the rocket fuel storage capacity, would be designed so that two completely refuelled propellant shuttles are enough for the Mars shuttle to launch from the surface of Mars and reach the gravity ring – waiting for it on Mars orbit –, and the remaining two fixing points would primarily be for emergency situations.



78. Fully established Mars base (Artist's Concept) (Credit: NASA)

The Mars shuttle, similarly to the original Orion MPCV by the redesign of which it has been created, would also be capable of transporting four astronauts, however, the astronauts would take three Mars shuttles with them to the mission on the surface of Mars, which would be connected to the gravity ring, allowing the group of four to land on Mars with two Mars shuttles in order to reduce risks, and they would still have a reserve emergency Mars shuttle connected to the gravity ring, which would be on geostationary orbit above the planned location of the Mars base.



79. Rover and astronaut meet (Artist's Concept) (Credit: Pat Rawlings)

The separate landing of the two Mars shuttles and the use of crews of only two crew members each is important not only to ensure that in case one of the Mars shuttles were to suffer a fatal accident during landing, allowing the mission on the surface of Mars to proceed with the two surviving astronauts, but also due to the fact that the LOX/LH2 rocket engines and the related cryogenic rocket fuel tanks installed in the crew module of the Mars shuttle require a lot of space, which can only be provided by minimising the inner habitat of the astronauts.



80. All-Terrain Hex-Limbed Extra-Terrestrial Explorer (ATHLETE) rovers with crew module mockups (Credit: NASA)

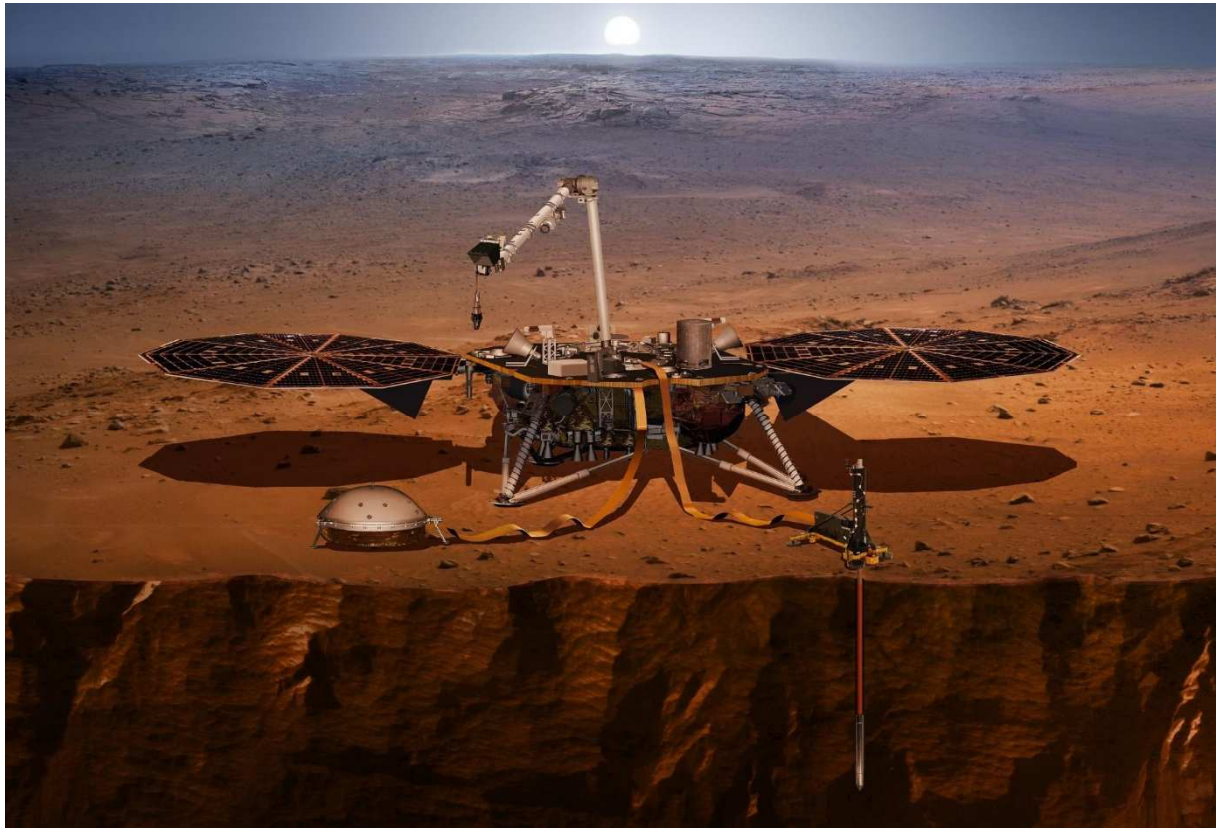
The Mars shuttle detached from the gravity ring on geostationary orbit would start landing by descending into the atmosphere and using its primary heat shield for aerodynamic braking, and then the Mars shuttle would deploy supersonic parachutes from the tip of its crew module to further assist braking. Once the velocity of the Mars shuttle has decreased so much that the heat shield of the service module is no longer needed, the Mars shuttle would dispose of the primary heat shield on the bottom of the service module. When closing in on the surface of Mars, the supersonic parachutes would also be disposed of by the crew module of the Mars shuttle; the Mars shuttle would keep on braking with rocket engines by igniting the main LOX/LH2 rocket engines of the service module, and then would land on the ATHLETE robotic legs opened in the meantime.

3.2 Emergency Situations when Landing the Mars Shuttle

Compared to traditionally designed spacecrafts – e.g. the SpaceX Starship or the Lockheed Martin Mars Lander –, there would be much more opportunities to act in case of an emergency, as the Mars shuttle would consist of two separate parts: the crew module and the service module. The capabilities of the rocket engines and of other subsystems of the Mars shuttle, as well as the storage

capacity of the liquid hydrogen and liquid oxygen rocket fuel tanks would be designed to be capable of handling the emergency situations mentioned in the following examples.

In case the primary heat shield of the Mars shuttle were to operate perfectly upon entering the atmosphere, but the supersonic parachutes would open incorrectly, or would not open at all, the crew module of the Mars shuttle would ignite its own LOX/LH2 rocket engines on the side to decelerate the entire Mars shuttle until the velocity of the Mars shuttle is decreased so that the primary heat shield is not needed anymore as an air flow deflector, and the disposal thereof would allow the ignition of the main rocket engines of the service module.



81. InSight Lander (Artist's Concept) (Credit: NASA)

In case the primary heat shield of the Mars shuttle is damaged, e.g. by a micrometeorite impact, and is therefore rendered unable to properly transfer the heat caused by friction upon entering the atmosphere, the crew module of the Mars shuttle would ignite its own LOX/LH2 rocket engines on the side for a moment, until the heat – monitored constantly by sensors – exceeds a level considered safe, and would perform an emergency detachment from the service module by releasing the clamping handles. After this, the crew module's own heat shield would perform further aerodynamic braking.

Once decelerated to the proper velocity, the crew module, which now would be flying by itself, would deploy the supersonic parachutes, which the crew module would not dispose of in this emergency situation while closing in on the surface of Mars, exploiting deceleration provided by the supersonic parachute until the very last moment. When reaching the close proximity of the surface, the crew module would use all of its LOX/LH2 rocket fuel to decrease the power of impact through braking with the rocket engines for a few moments.



82. Lockheed Martin Mars Lander (Artist's Concept) (Credit: Lockheed Martin)

Since the crew module of the Mars shuttle would not be provided with landing gear, the seats of the astronauts would specifically be designed to mitigate forces of extremely rough landings – practically considered as impacts –, so that astronauts would have a chance of survival in these cases as well. The astronauts would wear SpaceX Starman spacesuits inside the Mars shuttle, so that casing damages to the crew module would not be fatal for astronauts even if damages were to affect the inner pressurised habitat.



83. Mission on the surface of Mars (Artist's Concept) (Credit: NASA)

In case the aerodynamic braking of the Mars shuttle using the primary heat shield upon entering the atmosphere and the further deceleration with supersonic parachutes were to happen without any issues, but the disposal of the heat shield of the service module would fail, rendering the main rocket engines of the service module unusable, the Mars shuttle would decelerate by igniting the LOX/LH₂ rocket engines on the side of the crew module, where the crew module would not use its own liquid hydrogen and liquid oxygen rocket fuels, but that of the service module through the connection between the two modules.

Since the ATHLETE robotic legs of the Mars shuttle could not set in landing position without disposing of the primary heat shield, as soon as the service module runs out of all the rocket fuel, the crew module would perform emergency detachment by releasing the clamping handles, and would use its own rocket engines on the side with its own rocket fuel to land on the surface of Mars by itself.

In the absence of landing gear, even landing at a minimum velocity would cause serious damages to the crew module transporting the astronauts, but since it would land on its most durable structural element – that is, on the heat shield –, hopefully on a completely flat area on the surface of Mars without any larger rocks, the risk of injuries occurring to the astronauts could be reduced even in an emergency situation.

3.3 Structure and Operation of the Propellant Shuttle



84. The propellant shuttle (simplified illustration; not to scale) (Designed by with additional ideas: Roland Gadár)

1. Propellant shuttle. The propellant shuttle would use liquid hydrogen and liquid oxygen as rocket fuel similarly to the other landers, and since the propellant shuttle would specifically be designed for shipping LOX/LH₂ rocket fuel, unlike the other landers, it would not need to consume more than a third of the rocket fuel stored in its cryogenic tanks for landing on Mars. Due to the inverted conical shape of the propellant shuttle aligned with the Mars shuttle, both its liquid hydrogen tank and liquid oxygen tank located below the former might be spherical.

2. Heat shield. The heat shield of the propellant shuttle would not be disposable, which would mean a significant excess weight when launching from the surface of Mars, but this would make the propellant shuttle reusable, allowing the propellant shuttle in specific emergency situations to land on the surface of Mars once again after refuelling at the gravity ring. To this end, unlike the other Mars landers of Phoenix Program, the heat shield of the propellant shuttle would not be ablative, but instead, it would be made of ceramic tiles similarly to the Space Shuttle Orbiters.

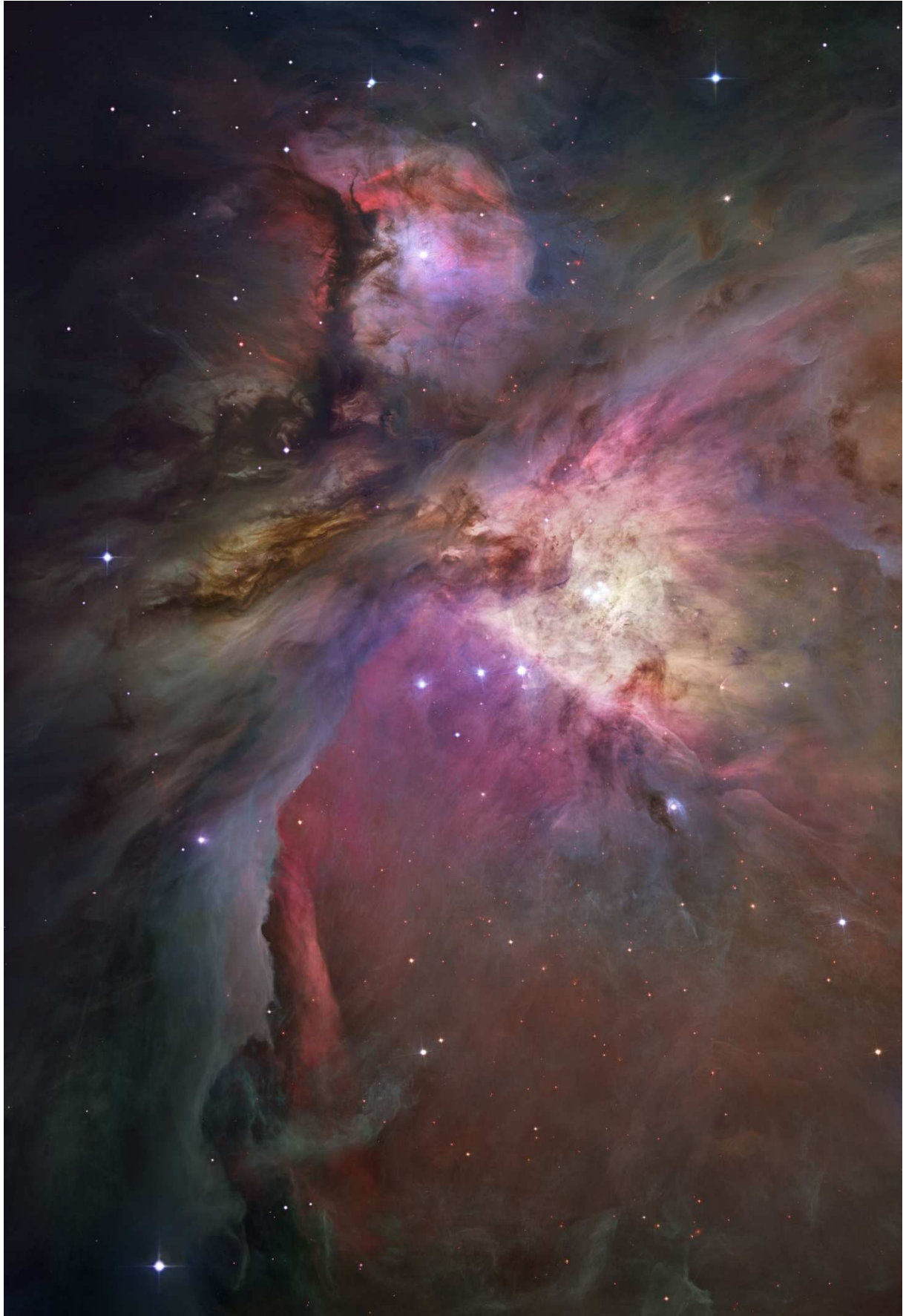
3. Fixing points for the Mars shuttle. These extremely heavy-duty fixing points would allow fixing the propellant shuttle to the service module of the Mars shuttle. As the propellant shuttles could not be connected to one another, only to the Mars shuttle, the propellant shuttle would only have two fixing points – unlike the Mars shuttle –, one for the Mars shuttle and one as a reserve in case the first one were to malfunction. Connecting the Mars shuttle and the propellant shuttles through the fixing points would also establish a power- and data link between the shuttles, allowing the on-board computer of the Mars shuttle to control the propellant shuttles directly during the launch, however, these fixing points would not be able to distribute the LOX/LH2 rocket fuel. Rocket fuel could only be transferred from or resupplied to the propellant shuttles through the resource-distribution connectors of each Mars lander, which wouldn't play any role when launching from the surface of Mars, which means that the Mars shuttle and the connected propellant shuttles would consume LOX/LH2 rocket fuel from their own cryogenic tanks when launching to reach Mars orbit.

4. ATHLETE robotic legs. The propellant shuttle, similarly to the Mars shuttle, would also use ATHLETE robotic legs for landing gear, however, due to its inverted conical shape, the propellant shuttle would have its heat shield on the top when landing on the surface of Mars, and therefore, unlike the Mars shuttle, the propellant shuttle would release its ATHLETE robotic legs to landing position from the sides. Using ATHLETE robotic legs both for the Mars shuttle and the propellant shuttles would allow these landers to approach one another individually on the surface of Mars, and then, to connect through remote controlling, by levelling their fixing points precisely.

5. Main LOX/LH2 rocket engines. Unlike the Mars shuttle, the propellant shuttles would have thrust-controlled main rocket engines which could be restarted several times and could be used without disposing of the heat shield. Since the supersonic parachutes of the propellant shuttle would open next to the main rocket engines upon entering the atmosphere, the propellant shuttle, after disposing of the supersonic parachute, would completely turn upside down to ignite the main rocket engines and land on the surface of Mars by braking with the rocket engines.



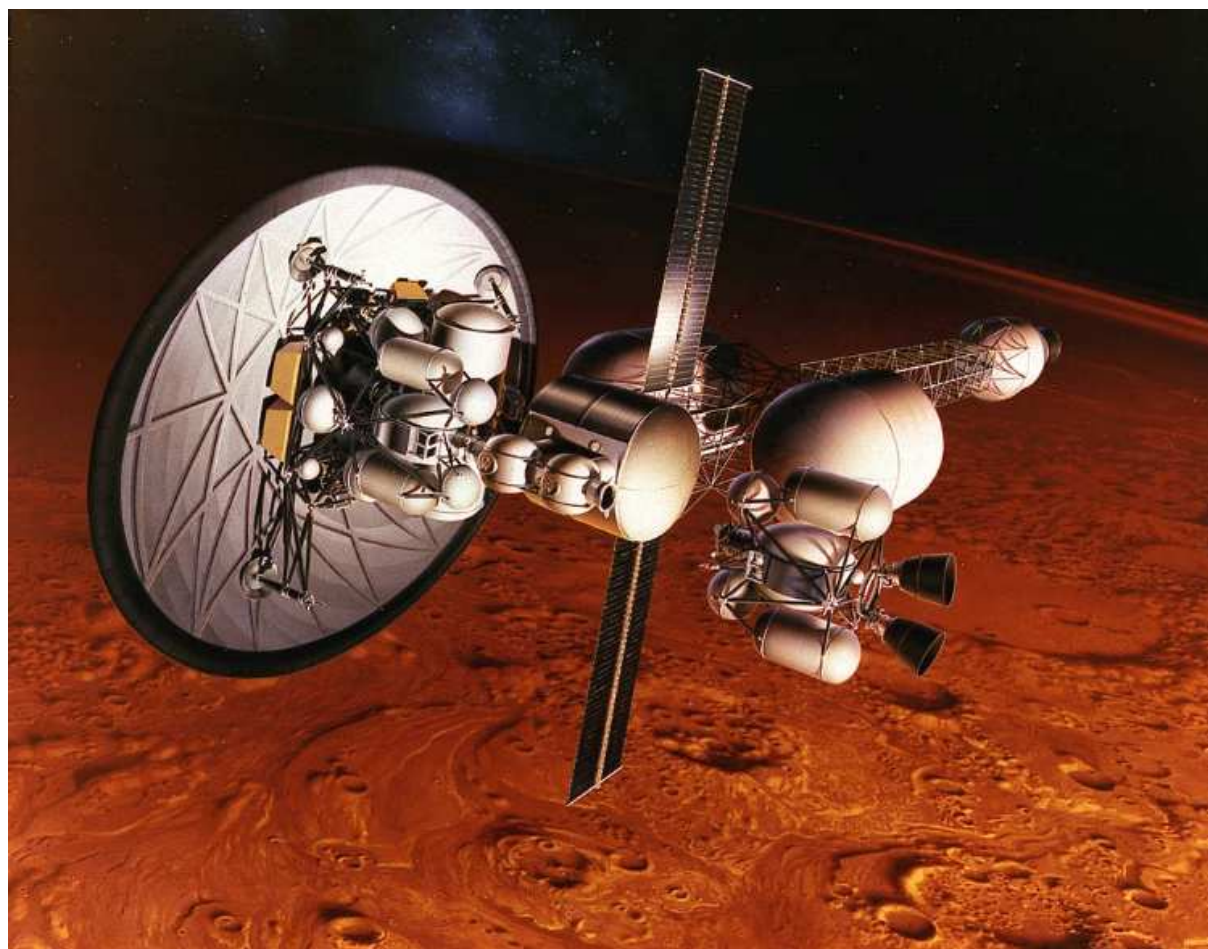
85. Twin Peaks on Mars (Credit: NASA)



86. Orion Nebula (Credit: NASA)

The propellant shuttle would be provided with high-performance cooling equipment, which, together with the proper thermal insulation of the cryogenic tanks, would be able to prevent the LOX/LH₂ rocket fuel from evaporating on the surface of Mars, where temperature is much more comfortable than in space.

Similarly to the other landers, the primary power supply of the propellant shuttle would also be fuel cell consuming gaseous hydrogen and oxygen, ensuring the operation of the ATHLETE robotic legs actuated by electric motors after landing, as well as keeping the LOX/LH₂ rocket fuel sent to the surface of Mars liquefied by operating the cooling equipment of the cryogenic tanks constantly.



87. A nuclear-thermal rocket with an aerobreaker disk as it orbits Mars (Artist's Concept) (Credit: NASA)

Energy production with fuel cells might entail the consumption of a great deal of rocket fuel, but the nuclear supply module would take over the role of power supplier of every Mars lander when the Mars base is established, and the propellant shuttle would also be provided with a rocket fuel recirculation system, which could decompose water – produced through energy production with fuel cell – to hydrogen and oxygen, which the cooling equipment of the propellant shuttle could cool down and turn into liquid state, which then could be returned into the cryogenic rocket fuel tanks.

Since all the landers would be connected through the resource-distribution connectors when establishing the Mars base, the propellant shuttles could produce LOX/LH₂ rocket fuel from the water produced by the operation of the fuel cells of the other landers.

A total of eight propellant shuttles would be manufactured for the Mars mission, which would be connected to the gravity ring on low Earth orbit with the help of SpaceX Falcon Heavy launch vehicles. Since these propellant shuttles would be able to cool the stored LOX/LH2 rocket fuel constantly, and their cooling equipment could be provided with energy by the iROSA solar panels of the gravity ring, the propellant shuttles could take the trip between the Earth and Mars in a completely filled condition.

The importance thereof would be significant in an emergency where the use of the stabilisation gas distribution system of the gravity ring is rendered impossible, e.g. by a series of micrometeorite impacts. In this case, the mission would be aborted, and then the astronauts could safely return home aboard the gravity ring by using the LOX/LH2 rocket fuel of the propellant shuttles which was originally intended to be used for the mission on the surface of Mars.



88. Launching samples home from Mars (Artist's Concept) (Credit: NASA)

Another extreme emergency situation is where the astronauts are forced to leave the gravity ring e.g. due to an explosion. In this case, four completely filled propellant shuttles would be connected to a Mars shuttle through the fixing points on its side in deep space, and then the life-supporting

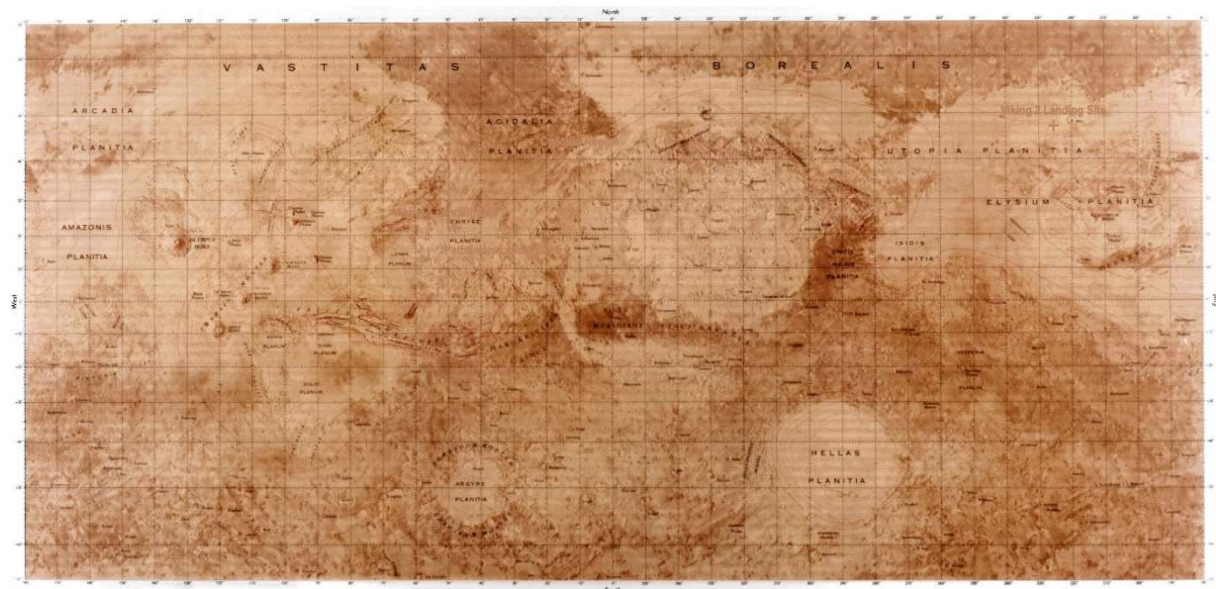
space station module – detached from the gravity ring in the meantime – would be connected to the docking port on the nose of the Mars shuttle, while the space habitat module would remain connected to the docking port on the other end of the life-supporting space station module. This would result in the quick and simple assembly of a deep-space spacecraft, which would not have artificial gravity, but would be sufficient and suitable to return the astronauts safely to low Earth orbit.

3.4 Nuclear Supply Module

Since all the Mars landers would use ATHLETE robotic legs for landing gear, the landing zone of each lander could be assigned by taking safety into consideration – instead of the scientific tasks planned to be performed on the surface of Mars –, as the landers could simply move to the areas assigned for research after landing.

Regardless of the above, the landing zone designated for the landers and the location planned for establishing the Mars base for the first Mars mission would be the same, even if the landing zone considered as the most ideal due to the terrain is not the most attractive in scientific aspects.

The first mission on the surface of Mars would take place along the equator of Mars, where temperature is the most hospitable, allowing the reduction of energy demands from the constant heating of the Mars base, and where the initial velocity resulting from the rotation of Mars could be exploited fully when launching from the surface of Mars.



89. The map of Mars (Credit: NASA)

The landers, thanks to their ATHLETE robotic legs, would be capable of relocation even after being connected to each other in order to establish the Mars base, by moving the entire Mars base to a location where searching for water and life on Mars is more ideal – e.g. to a former stream bed –, however, this unrestricted mobility would be lost as soon as the astronauts need to build a farm of solar panels for the constant power supply of the Mars base, and for this reason, for the mission on the surface of Mars, the primary power supply of Phoenix Program would be a nuclear supply module using the results of NASA Kilopower development project.



90. Westerlund 2 star cluster (Credit: NASA)

Since sending a nuclear reactor with a large amount of radioactive material poses a significant risk, as a fatal accident might result in the radioactive material contaminating a vast area, the nose cone with the nuclear supply module would be equipped with a short-combustion, high-thrust launch escape system upon launching with the SpaceX Falcon Heavy launch vehicle, which, unlike traditional launch procedures, would not be disposed of together with the nose cone, but would accompany the nuclear supply module all the way. With this, similarly to the NTP engine module, the nuclear supply module would also be provided with an emergency ejection system on the way to Mars in order to be able to quickly move away from the gravity ring. The launch escape system would only be detached from the nuclear supply module on Mars orbit, when preparing for landing on the surface.

As for the location of the heat shield and the main LOX/LH2 rocket engines, the nuclear supply module would have a structure similar to that of the propellant shuttle, and the nuclear supply module would also turn completely upside down after disposing of the supersonic parachutes to ignite the main rocket engines and land by braking with the rocket engines.

As the uranium-235 used as fuel for energy production is radioactive, there would be no airlock or pressurised habitat for the astronauts in the nuclear supply module, allowing the sidewalls of the nuclear supply module to act as titanium heaters circulating distilled water for the nuclear reactor of no less than 10 kW rated power.

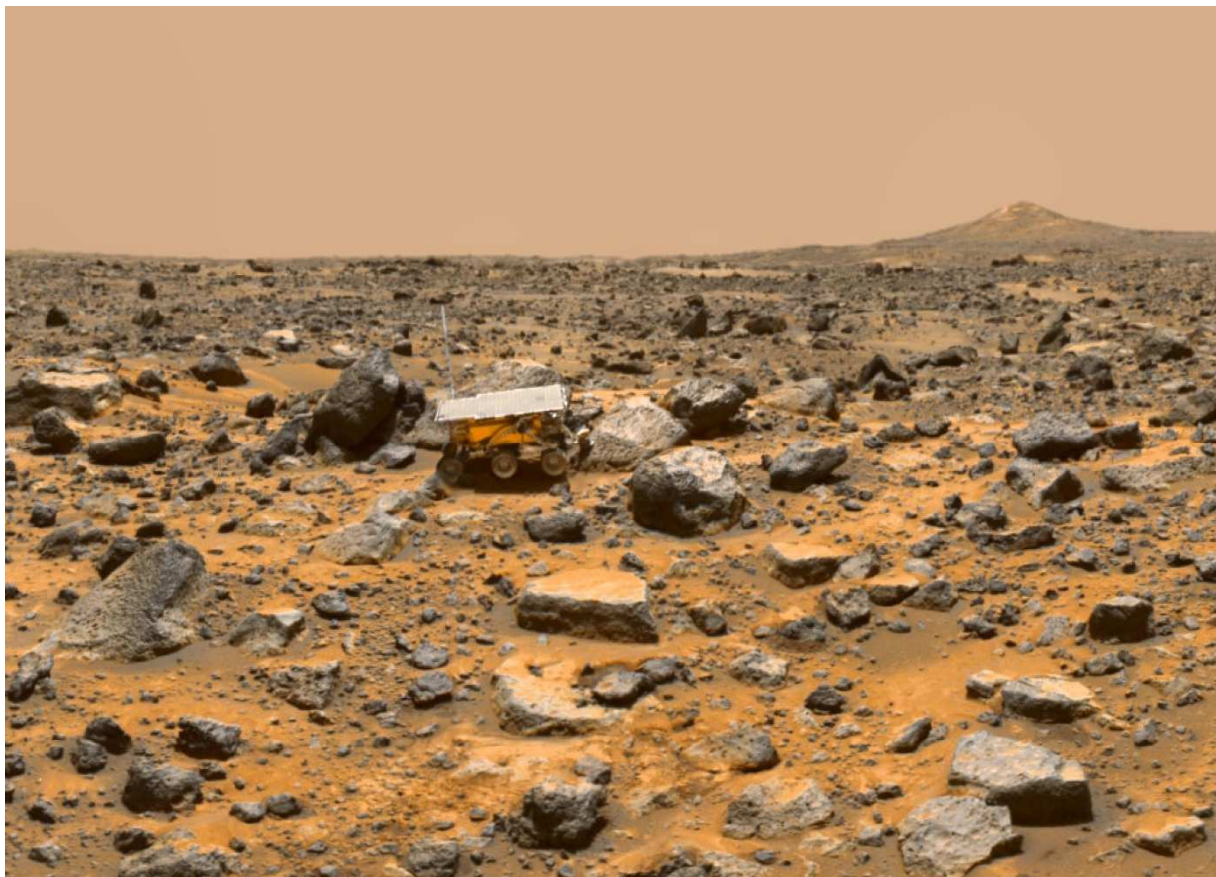
After landing on the surface of Mars, the nuclear supply module would use its own ATHLETE robotic legs to move to the planned location of the Mars base, and since the nuclear supply module, similarly to the other Mars landers, would also be provided with resource-distribution connectors, the astronauts could use the flexible, multi-purpose charging cables to connect the nuclear supply module with the other landers assembled at the location designated for establishing the Mars base.



91. NASA Astronauts on Mars (Artist's Concept) (Credit: NASA)

In order to reduce radiation exposure caused by the nuclear supply module inflicting the astronauts as much as possible, the propellant shuttles would be placed between the nuclear supply module and the base modules acting as the habitat of the Mars base when assembling the landers to establish the Mars base, so that the large volumes of liquid hydrogen and liquid oxygen stored in the propellant shuttles could have a significant shading effect.

Similarly to the propellant shuttles, the nuclear supply module would also be equipped with a high-performance cooling system, allowing it to store the LOX/LH2 rocket fuel remaining inside in liquid state as long as needed after landing, however, all remaining liquid hydrogen and liquid oxygen would be pumped from the nuclear supply module, from the Mars exploration vehicles and from the base modules into the propellant shuttles once the Mars base has been established.



92. Pathfinder on Mars (Credit: NASA)

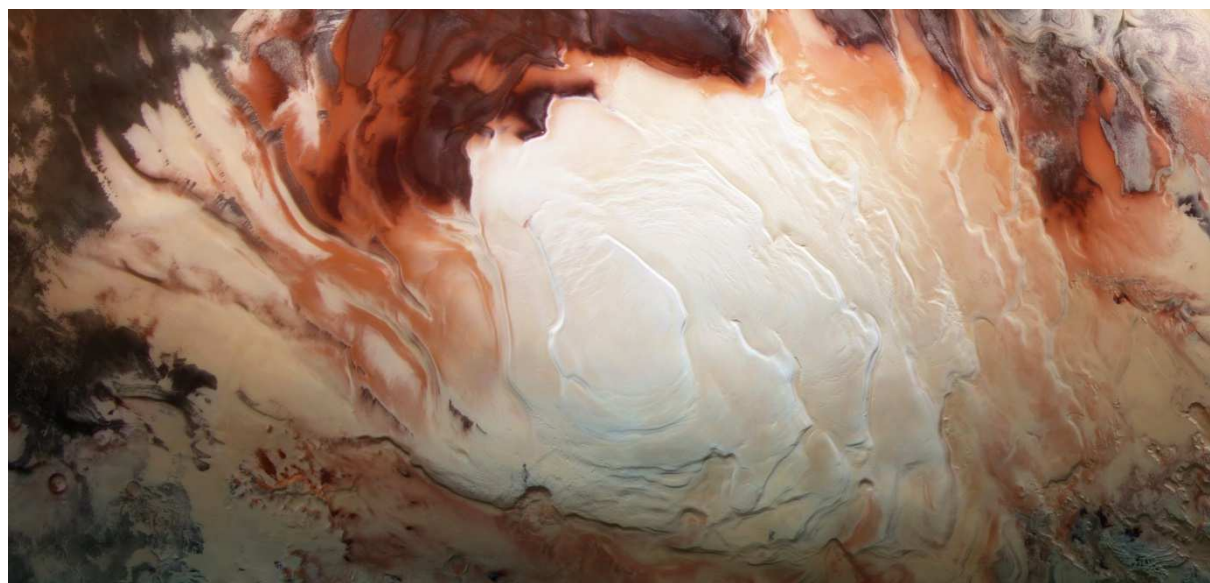
The nuclear supply module with depleted cryogenic tanks could thereafter supply the Mars base with constant power, and would also produce oxygen for the astronauts to breathe, allowing to use as much liquid oxygen delivered to the surface of Mars with the landers to be used as rocket fuel components as possible.

For this, the nuclear supply module would be provided with an oxygen production device based on the technology of NASA MOXIE, which would produce oxygen and carbon monoxide from the carbon dioxide in the atmosphere of Mars. Through this process, the unnecessary carbon monoxide would simply be released into the atmosphere of Mars, while the precious oxygen would be stored by the nuclear supply module both in liquid- and gaseous state.

The power of the oxygen production device of the nuclear supply module would be the same as the maximum heat- and energy output provided by its reactor, however, throughout the mission on the surface of Mars, the nuclear supply module would always consume only the currently available energy surplus to produce oxygen. Moreover, prior to accumulating oxygen in liquid state in the dedicated cryogenic tanks, the nuclear supply module would first fill the depleted liquid hydrogen tank with gaseous oxygen, because this oxygen would be the immediately accessible emergency oxygen supply of the astronauts and of the entire Mars base.

As the energy- and oxygen producing ability of the nuclear supply module would remain even after the end of the mission on the surface of Mars, and since the astronauts, under normal circumstances, would only need four out of the eight propellant shuttles that landed on Mars to return to the gravity ring on Mars orbit, the nuclear supply module could prepare for the next Mars mission once the astronauts have left, and could store the constantly produced oxygen in liquid state in its own cryogenic tanks as well as in the cryogenic tanks of the propellant shuttles equipped with cooling system.

With this, having a fully established Mars base and oxygen produced constantly, the next Mars mission – which could be started many years later at the earliest – would need to deliver much less devices and rocket fuel to the surface of Mars.



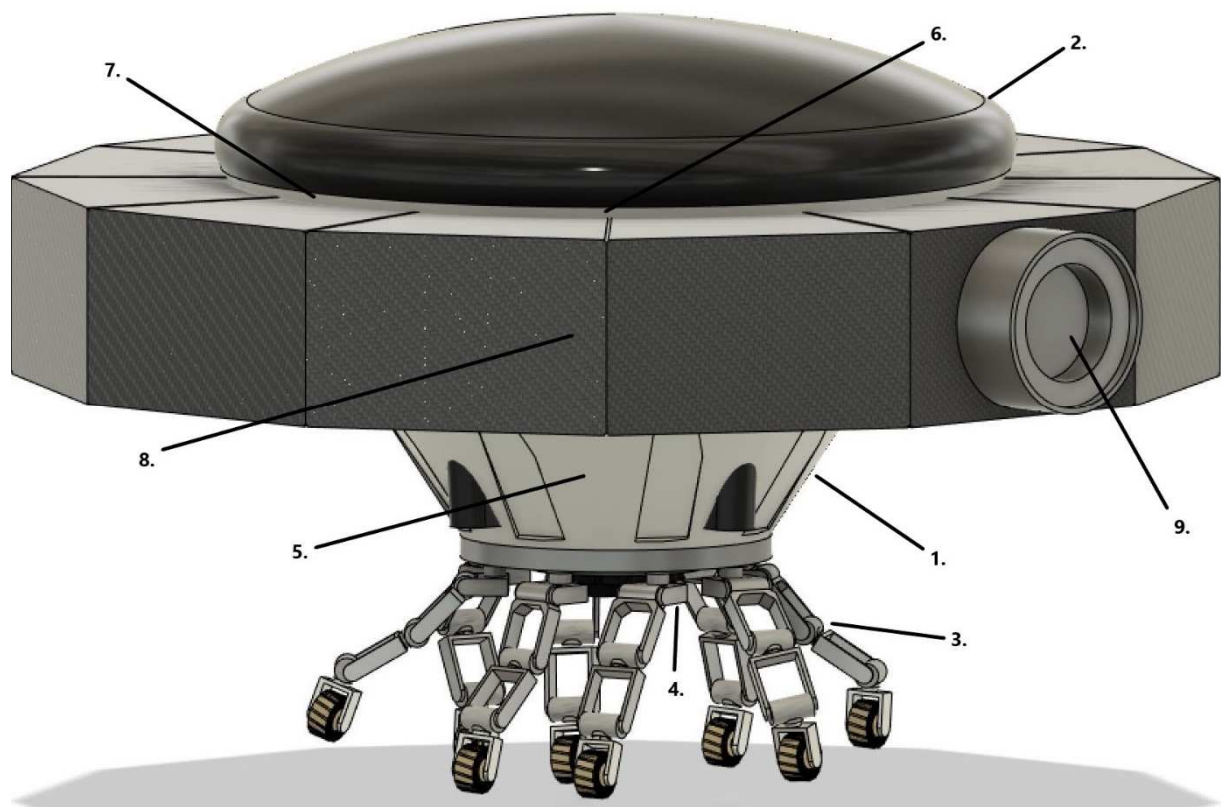
93. Martian south pole (Credit: ESA)

In accordance with the same principle, the nuclear supply module could also be sent to Mars by itself, so that it could arrive and start producing oxygen years before the first Mars mission would start; however, this nuclear supply module would play a pivotal role in reducing the risks of the mission in deep space due to its continuous and safe energy production, which is more important than the amount of oxygen it could produce in advance. Even if several nuclear supply modules could be manufactured for the Mars mission, only one would land on the surface of Mars with the astronauts, while the other ones would remain connected to the gravity ring as emergency reserves, and return to the Earth together with the astronauts upon the completion of the mission on the surface of Mars.



94. Monkey Head Nebula (Credit: NASA)

3.5 Structure and Operation of the Base Modules



95. A base module (simplified illustration; not to scale) (Designed by with additional ideas: Roland Gadár)

1. Base module. The structure of the base modules to be developed for different tasks to be performed on the surface of Mars would be similar to that of the propellant shuttle and the nuclear supply module with regard to the heat shield, the ATHLETE robotic legs and the allocation of the main rocket engines, and therefore, the landing of the base modules on the surface of Mars would also occur in the same manner.

2. Heat shield. As the base modules, similarly to the nuclear supply module, would remain permanently on the surface of Mars, the base modules would also be equipped with ablative heat shield, which would not be disposable, so that these heat shields – which would be on the top of the modules after landing on the surface of Mars – could be exploited as an extra radiation-absorbing layer, which, due to the high intensity of unimpeded cosmic ray showering the surface of Mars, is of utmost importance in the absence of a magnetic field and a thick atmosphere.

3. ATHLETE robotic legs.

4. Main LOX/LH2 rocket engines.

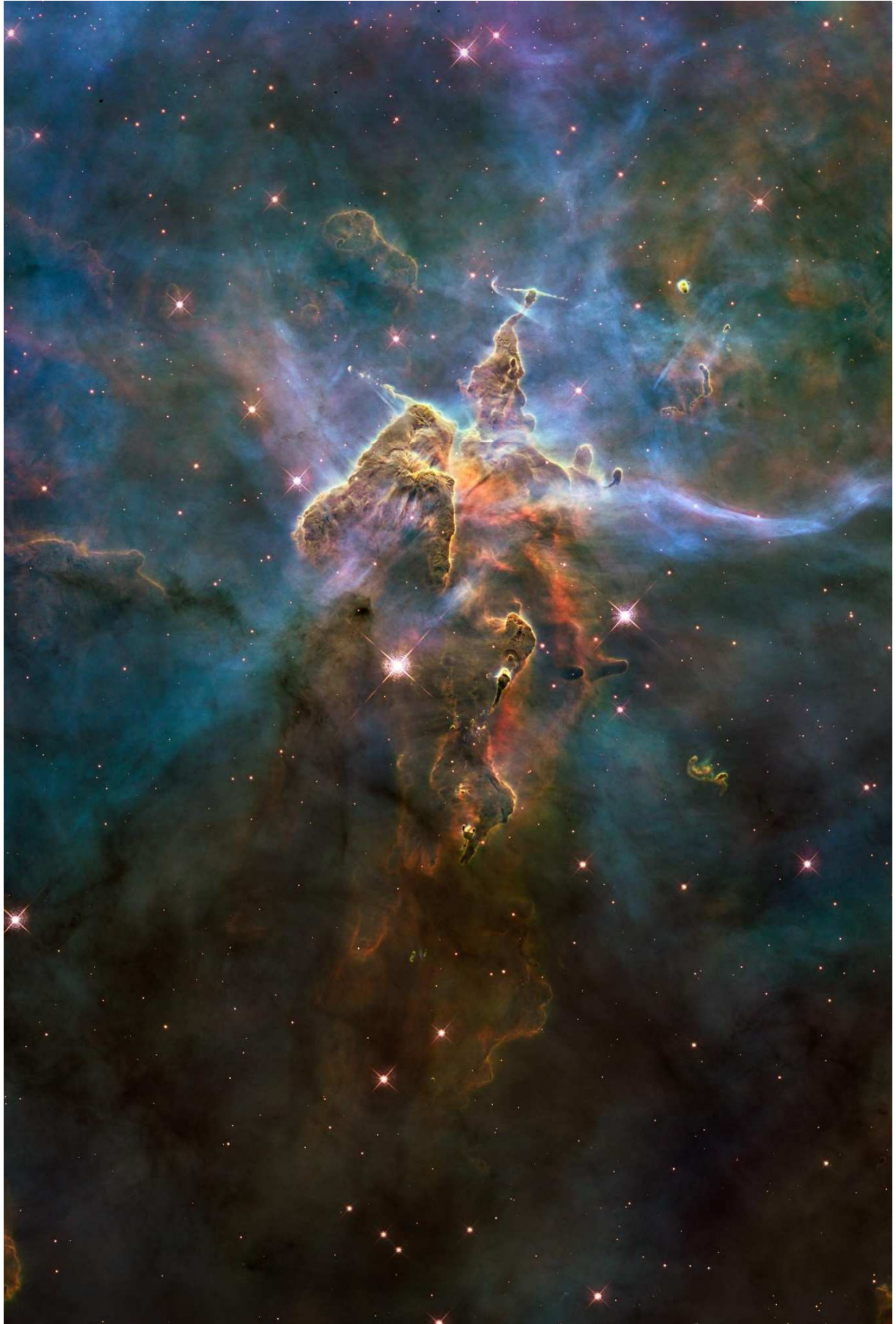
5. Liquid oxygen tank. Since the base modules would need to be able to store only the amount of LOX/LH2 rocket fuel in their cryogenic tanks that they need to move away from the gravity ring on geostationary orbit until landing on the surface of Mars – which amount the base modules would consume completely –, the cryogenic tanks of the base modules would have different shapes with a storage capacity much smaller than the cryogenic tanks of the propellant shuttles.

6. Liquid hydrogen tank. Unlike the spherical liquid hydrogen tanks of the propellant shuttles, the liquid hydrogen tanks of the base modules would be cylindrical, as these empty, pressure-tight cylindrical tanks with a diameter of no less than three metres would serve as the primary habitats of the astronauts after the landers – forming the Mars base – are connected and the rocket fuel remaining in the base modules is pumped into the propellant shuttles. To this end, the entire internal surface of the liquid hydrogen tanks of each base module would be provided with small boreholes at approximately ten-centimetre intervals, allowing the astronauts to furnish their primary habitat by bolting threaded hooks into the boreholes to hang screens, shelves, different devices and equipment. To operate these devices and equipment, the liquid hydrogen tanks of the base modules would already be provided with water-, air-, power- and data access points to which the astronauts could connect any devices and equipment they place into the cryogenic tanks by using extension cables. The greatest advantage of the liquid hydrogen tanks' convertibility into the primary habitats of the base modules is that a large and pressure-tight component of the landers would be utilised after landing, the thick aluminium casing of which would have a significant radiation-absorbing ability, providing a great contribution to reducing risks to human health on the surface of Mars, which is scarcely protected against cosmic ray.

7. Pressure-tight door. In order to allow the astronauts to enter the cryogenic tanks serving as the primary habitats of the base modules, as well as to leave those and enter the surrounding secondary habitats, both ends of the liquid hydrogen tanks of the base modules would be provided with a large and round pressure-tight door.

8. Pre-packaged equipment. Since nothing can be placed inside the cryogenic tanks to be used as the primary habitats of the astronauts until the Mars base is established and the cryogenic tanks are depleted, all the equipment of the base modules specialised for different tasks would be stored around the cryogenic tanks, practically packed in single blocks. The disadvantage of this is that the astronauts will have to spend weeks on furnishing the interior of the Mars base before they could start working on the scientific tasks of the Mars mission, unpacking and checking each and every device and equipment one by one before placing them permanently. The advantage of this, however, is that placing the equipment on each base module prior to being launched from the Earth could be done in an optimised manner with regard to space utilisation and weight distribution, allowing to exploit each free square centimetre in the base modules to store devices and equipment, as well as to ship different reserves to Mars.

9. Inflatable sidewalls. To establish the secondary habitats surrounding the cylindrical liquid hydrogen tanks, the fixation of the outer casing of the base modules could be removed, allowing to inflate the donut-shaped secondary habitats based on the technology of Bigelow Aerospace. Similarly to the cryogenic tanks forming the primary habitats of the base modules, these secondary habitats would also be pressurised spaces, and the resulting extra cubic metres would allow the astronauts to easily access the tightly pre-packaged equipment of the base modules, providing sufficient space to unpack and check those before placed permanently.



96. Carina Nebula (Artist's Concept) (Credit: NASA)

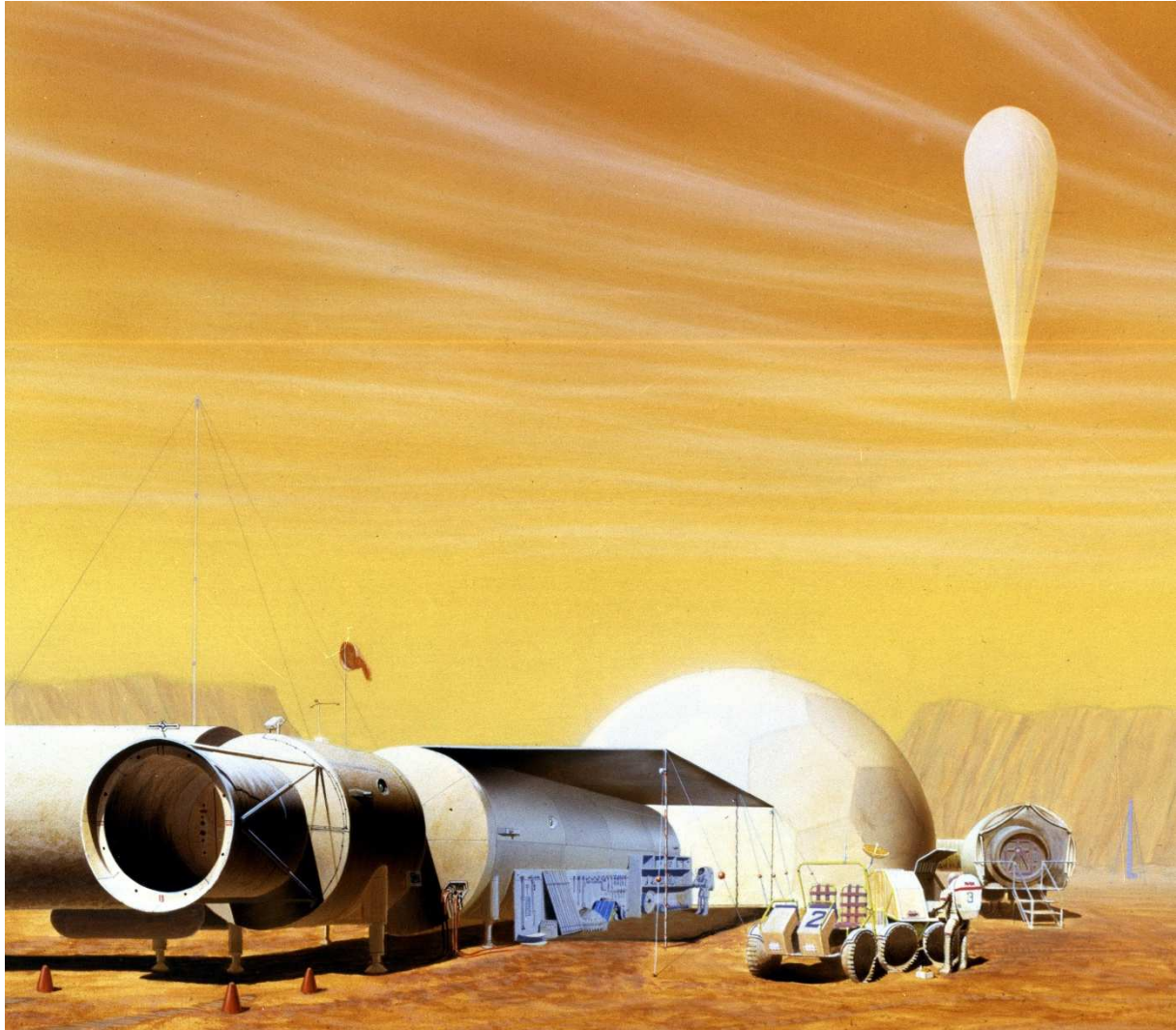
For each base module, the outer casing of the secondary habitats to be inflated into a donut shape would have two airlocks installed in advance, which would be on the opposite ends of the secondary habitats after inflation, becoming the outermost elements of the base modules. After rolling the base module next to each other, levelling them and precisely adjusting their relative height with the ATHLETE robotic legs, the base modules could be connected to one another through the airlocks, establishing a fully interconnective Mars base.



97. Martian habitat with colonists (Artist's Concept) (Credit: NASA)

Since every base module would be provided with two airlocks, the astronauts, when establishing the Mars base, could change the relative position of the different base modules as they wish, and once all the base modules are interconnected, they would still have two free airlocks to step out on the surface of Mars. A total of six base modules with the same structure, but specialised for different purposes, would be developed within the framework of Phoenix Program: the communications-, the workshop-, the recreational-, the scientific-, the shelter- and the aeroponic base module.

Similarly to the other Mars landers, the base modules would also be launched to the gravity ring on low Earth orbit with SpaceX Falcon Heavy launch vehicles, and upon reaching Mars, the six base modules would not land on the surface until all eight propellant shuttles have landed successfully. This is important because a mission on the surface of Mars would essentially be unachievable without the successful landing of the propellant shuttles, while different other base modules would primarily be relevant in the aspect of science and convenience – so that the astronauts, after landing with the Mars shuttles, would not have to spend only one or two days on the surface of Mars and collect rock samples in their immediate environment only, but could spend several months to perform a complex mission as they could rely on the resources of the Mars base.

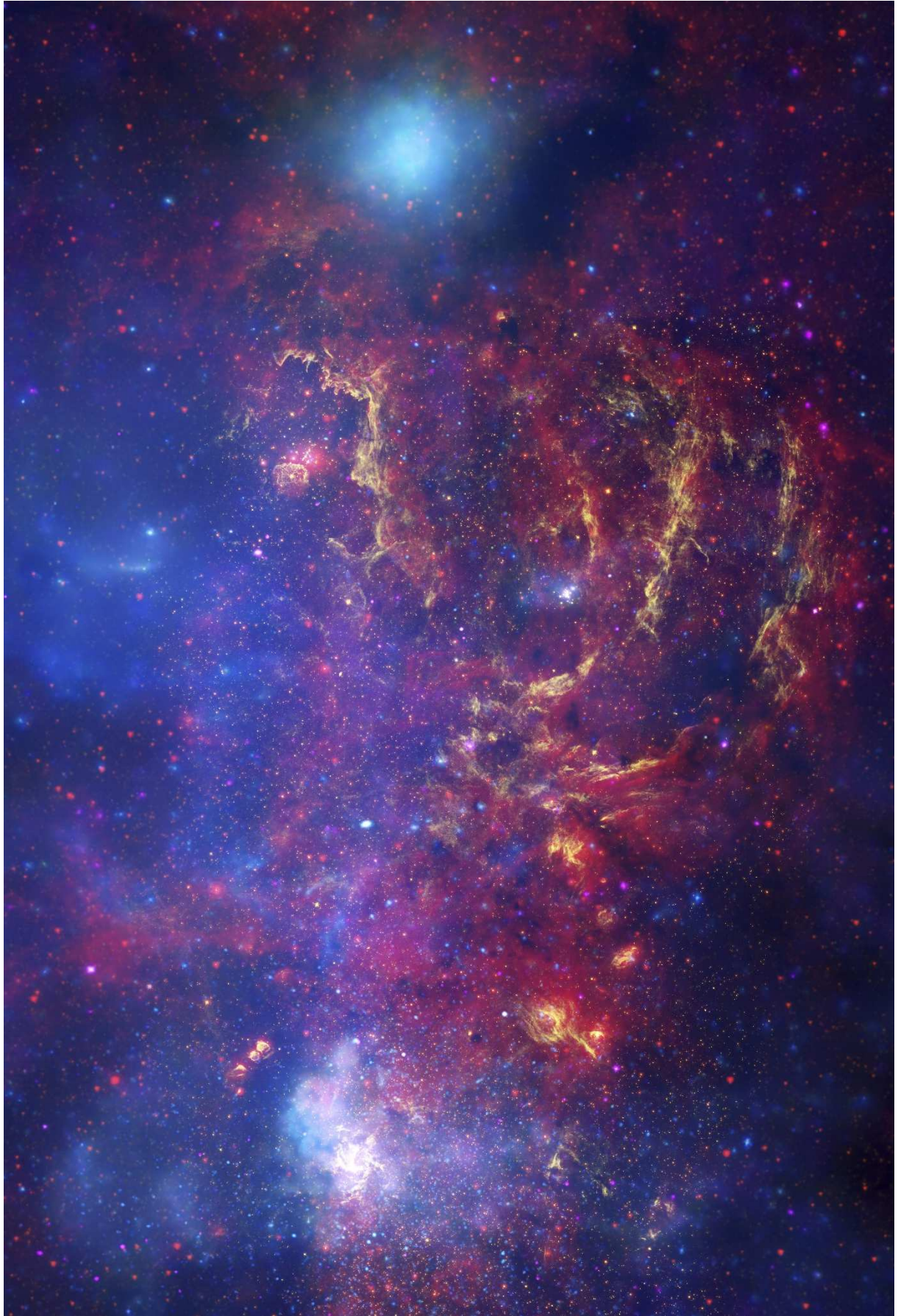


98. *Martian Outpost (Artist's Concept) (Credit: Mark Dowman)*

At the same time, sending eight propellant shuttles to Mars would also be a significant overcompensation for a mission on the surface of Mars, and therefore, in case any of those would be destroyed or rendered unusable during the landing, the mission could still be completed without any risks. Even the loss of two propellant shuttles during the landing would not result in the abortion of the mission on the surface of Mars, however, in this case, only two – instead of four – astronauts would land on the surface of Mars in one Mars shuttle in order to reduce risks and to ensure the feasibility of the emergency protocols.

3.6 Mars Exploration Vehicle

The MMSEV-based Mars rover still under development by NASA would not be used in Phoenix Program, as all research-related transportation of the astronauts on the surface of Mars would be provided by a lander with a structure similar to that of the base modules. The most significant difference between the Mars exploration vehicle and the base modules is that the depleted liquid hydrogen tank in the exploration vehicle would not act as a primary habitat, but also as a wind tunnel for dust filtration.



99. The central region of the Milky Way galaxy (Credit: NASA)

Since Mars dust poses a very serious risk to the health of the astronauts, and the astronauts could bring Mars dust to the sterile pressurised environment of the Mars base on their spacesuits and different equipment, the astronauts should always dedust themselves perfectly before entering the Mars base.

For this, the liquid hydrogen tank of the exploration vehicle would be equipped with air-pipes in advance for the wind tunnel, which would be closed until the liquid hydrogen remaining in the cryogenic tank is pumped into the propellant shuttles, allowing the cryogenic tank to be used as a deduster. The return-stream air-pipes of the wind tunnel – to be transformed from the cryogenic tank – would be connected to a high-performance air-intake device, which could constantly dedust the air in the cryogenic tank by ventilating air through the dust filters, which the astronauts could clean and replace.



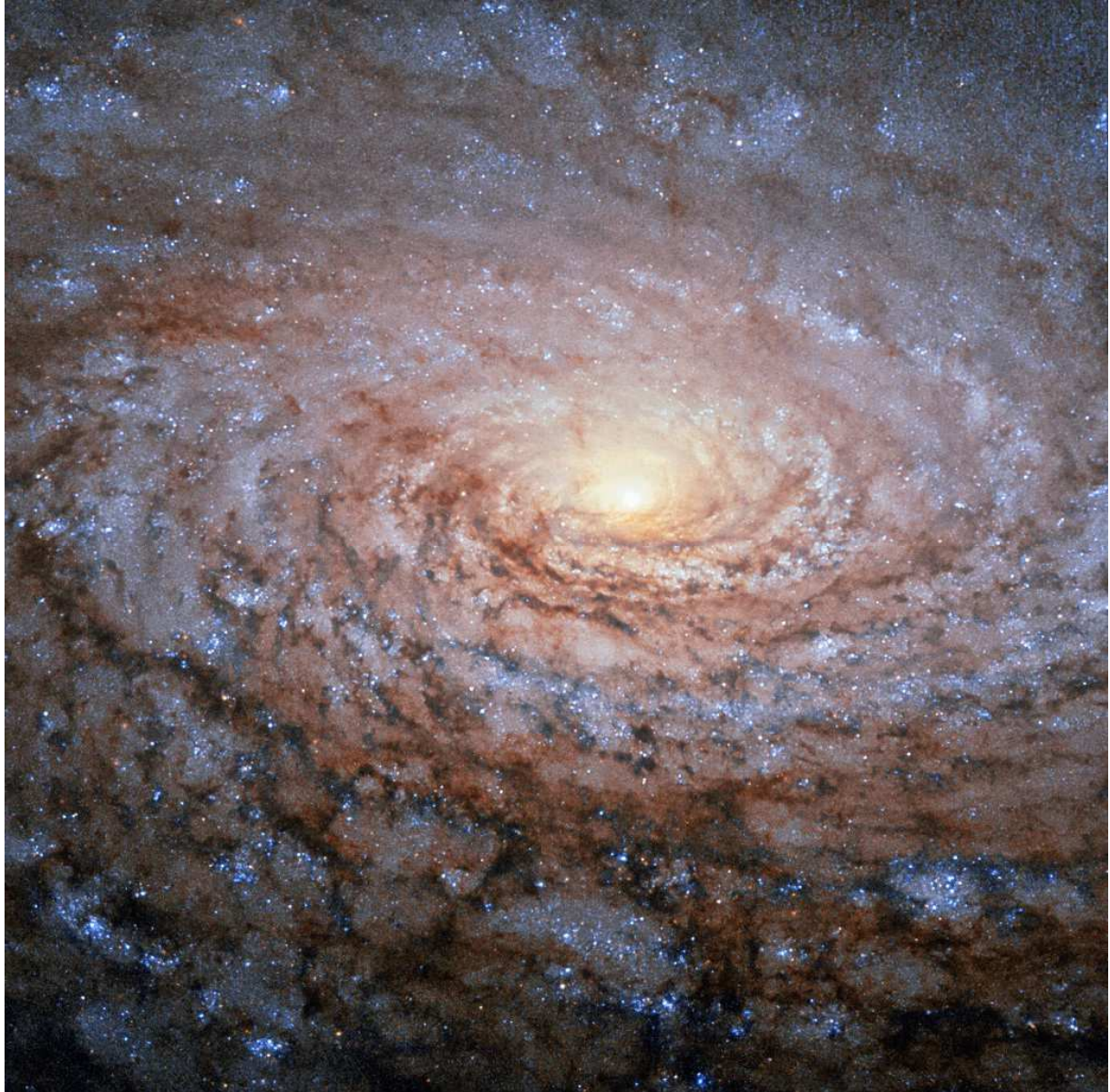
100. Landing on Mars (Artist's Concept) (Credit: Les Bossinas)

Since the astronauts have to dedust before taking off the spacesuit, the wind tunnel of the exploration vehicle would basically use the air of the Martian atmosphere consisting almost entirely of carbon dioxide for circulating the air – instead of using the breathable air of the Mars base –, making it simpler and faster for the astronauts to step into the wind tunnel from the surface of Mars.

As inserting the dust filters would allow the Martian air to circulate constantly at a high speed in the cryogenic tank to be used as a wind tunnel, the astronauts could remove Martian dust from the spacesuits and other surfaces with high-pressure nozzles.

Each of these high-pressure nozzles would be at the end of an air hose that looks like a robot snake, while the air hose would be connected to a carbon dioxide cylinder with a storage capacity of several tens of litres, allowing the astronauts to perfectly dedust the least accessible parts of their spacesuits and equipment using the compressed carbon dioxide released through the high-pressure nozzles. The carbon dioxide cylinders with high-pressure nozzles could also be carried in hand, allowing the astronauts to refill the cylinders outside of the wind tunnel.

The inner wall of the wind tunnel of the exploration vehicle would have its entire surface equipped with Electrodynamic Dust Shield (EDS), making it easier to keep the cryogenic tank clean at all times.



101. Sunflower Galaxy (Credit: ESA)

Unlike the base modules, the exploration vehicle would already have the two airlocks on the opposite sides connected to the cryogenic tank, so that once the donut-shaped secondary habitat is inflated, the astronauts would always go through one of the airlocks when entering or leaving the cryogenic tank serving as the wind tunnel.



102. Horsehead Nebula (Credit: NASA)

Since the wind tunnel of the exploration vehicle and its connected airlocks would divide the inflated, donut-shaped secondary habitat into two completely separate parts, one of these two semicircle-shaped habitats would serve as the pressurised passenger compartment, while the other semicircle-shaped part would be a large tool- and equipment storage room, open to the Martian atmosphere.

A large, non-pressure-tight door would be installed in the rear-facing wall of the tool- and equipment storage room of the exploration vehicle; this door would be equipped with retractable stairs with handrail, allowing the astronauts wearing xEMU spacesuits to enter and leave the room easily and safely.

This would allow having everything in the tool- and equipment storage room that the astronauts may need to use continuously during their works on the surface of Mars, which they would not have to take back to the pressurised, sterile environment of the Mars base after dedusting each and every time. The rock samples gathered from the surface of Mars would also be stored in the tool- and equipment storage room, minimising the chance of contamination by different organisms.

Both airlocks of the exploration vehicle could be left in four directions: outside, towards the surface of Mars, or towards the Mars base if the exploration vehicle has one of its airlocks connected to a free airlock of the Mars base; inside, into the cryogenic tank serving as the wind tunnel; sideways, towards the pressurised passenger compartment of the exploration vehicle; and finally, towards the tool- and equipment storage room, through an xEMU suitport.



103. Small Pressurized Rover with a view of astronaut suitports (Credit: NASA)

The astronauts could minimise the use of the wind tunnel and the time spent on dedusting by wearing the xEMU spacesuits to be worn by entering through the openings on the back, which are designed specifically for docking into the dedicated xEMU suitports; this solution allows the astronauts to leave both airlocks of the exploration vehicle towards the tool- and equipment storage room by directly entering the spacesuits through the xEMU suitports.

The surface of Mars is much more hospitable than the surface of the Moon or deep space, however, using xEMU spacesuits is still inevitable, because using other spacesuits, which are optimised for the surface of Mars, but are less adequate, would pose unnecessary risks.



104. Perseverance Mars rover (Credit: NASA)

As for the sidewalls of the exploration vehicle to be inflated into a donut shape, the anterior semicircle-shaped pressurised passenger compartment of the exploration vehicle would be designed to have windows after inflation, allowing the astronauts to have a view on the surface of Mars when driving the exploration vehicle with a joystick. This view might be minimal compared to that of an MMSEV-based Mars rover, but equipping the exploration vehicle with cameras would provide the astronauts with a good vision on the immediate environment of the exploration vehicle.

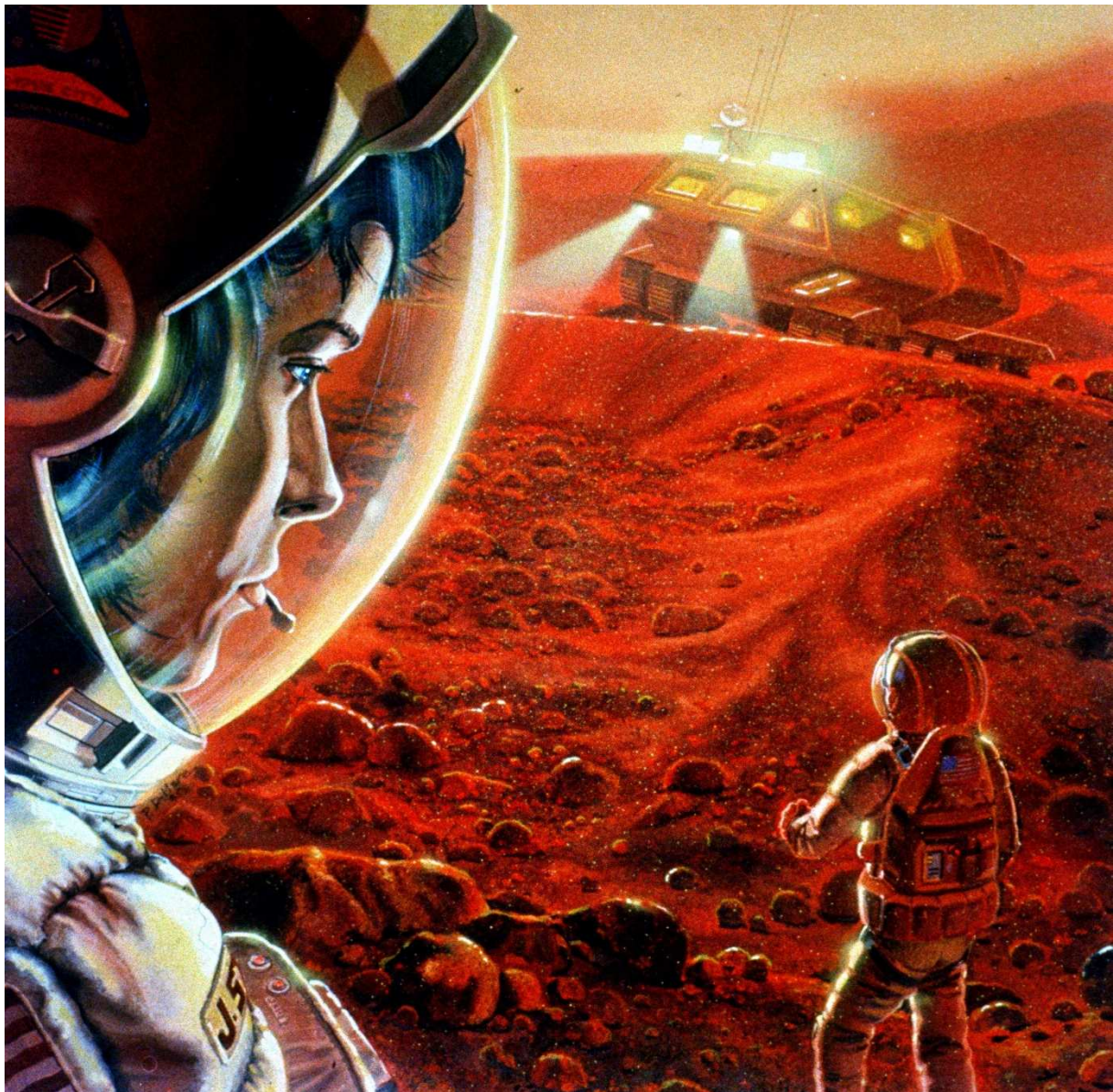
Similarly to the base modules, the exploration vehicle would also be provided with pre-packaged equipment: RTA seats, tools and equipment for installing the wind tunnel, and, among others, spare xEMU spacesuits. Unlike the base modules, however, the Mars exploration vehicle would specifically be designed to be ready for use immediately after draining its remaining LOX/LH2 rocket fuel and inflating its donut-shaped secondary habitat.

Similarly to the other Mars landers, the primary power supply of the exploration vehicle would also be fuel cell consuming gaseous hydrogen and oxygen, however, similarly to the base modules, the exploration vehicle could also use its fuel cell power supply only until the LOX/LH2 rocket fuel remaining from the landing is pumped into the propellant shuttles after establishing the Mars base.

After that, the exploration vehicle could only rely on its own integrated batteries for power supply at all times when it is not connected to the Mars base, that is, to the nuclear supply module thereof.

This might dramatically reduce the area the exploration vehicle could explore at a given time, but since Phoenix Program would primarily rely on robots for performing research duties throughout the mission on the surface of Mars, and the Mars base would maintain its mobility all along, and the astronauts themselves would never have to drift far away from the Mars base, which would significantly reduce the risks of the mission on the surface of Mars.

For this reason, the primary purpose of the exploration vehicle would not be to transport the astronauts between the Mars base and scientifically interesting areas on the surface of Mars, but to serve as an entrance to the Mars base, allowing the astronauts to dedust each time they return to the Mars base when they are not using the xEMU suitports, but the airlocks. Due to the pivotal role of dedusting during the mission on the surface of Mars, two Mars exploration vehicles would land on Mars, and one of these exploration vehicles would always be connected to the Mars base.

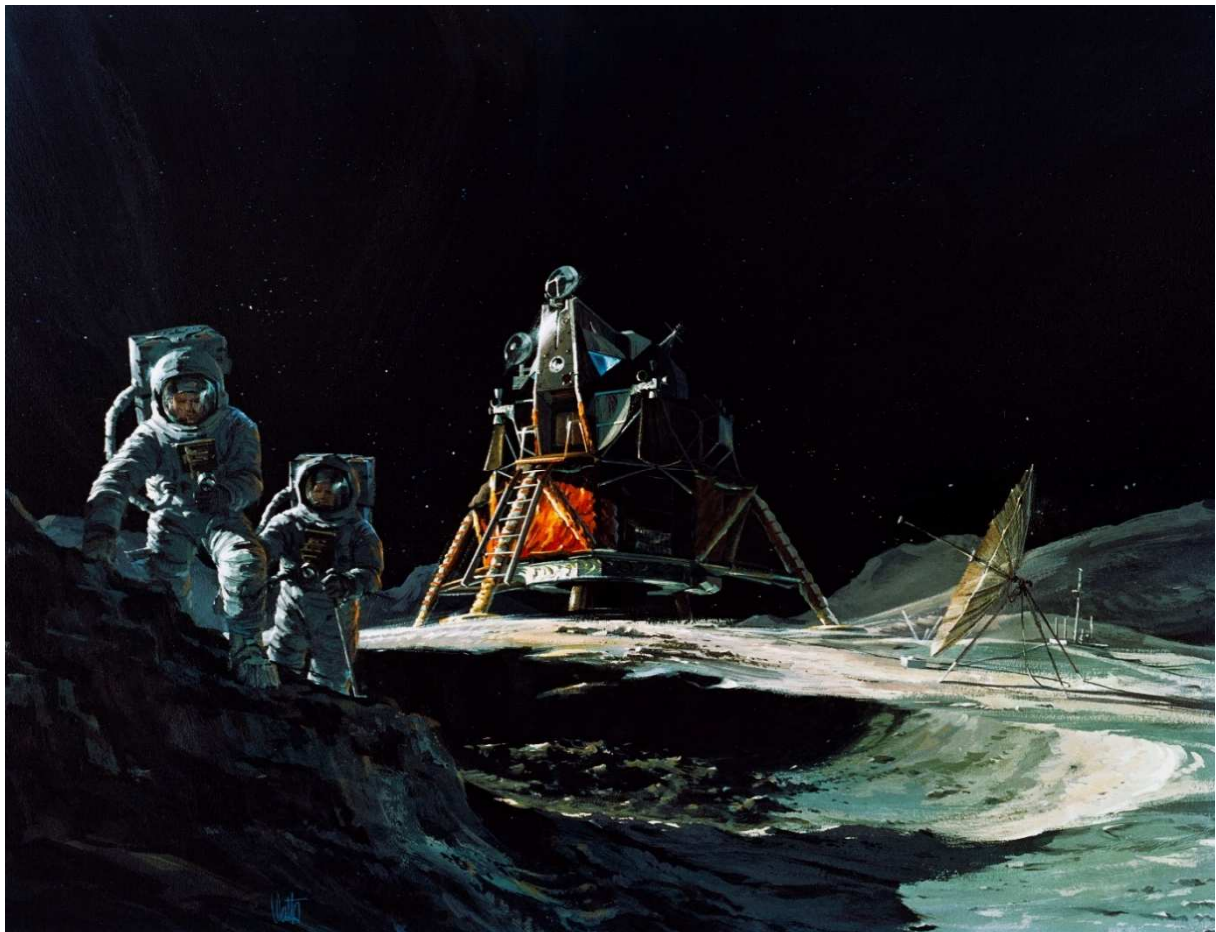


105. Astronauts in Martian dust storms (Artist's Concept) (Credit: Paul DiMare)

Chapter 4: Lunar Test Programme

While the surface of the Moon, in the absence of a magnetic field protecting against cosmic ray and solar flares, is just as dangerous for the astronauts as deep space, and while even with a proper protection against radiation, it would be impossible to operate a permanently manned Moon base due to the impact of one-sixth gravity on health – which would only be possible through the rotation of staff similarly to the International Space Station –, the Moon still offers considerable potential despite the disadvantages.

During a Mars mission, which may take up to two years, several devices and technologies will have to be used in a live situation, where deficiencies in the design and breakdowns may not pose an imminent danger to the astronauts, but would certainly render the execution of the scientific tasks of the mission on the surface of Mars impossible. For this reason, similarly to Artemis Program of NASA, Phoenix Program would also execute a comprehensive test programme at the Moon first.



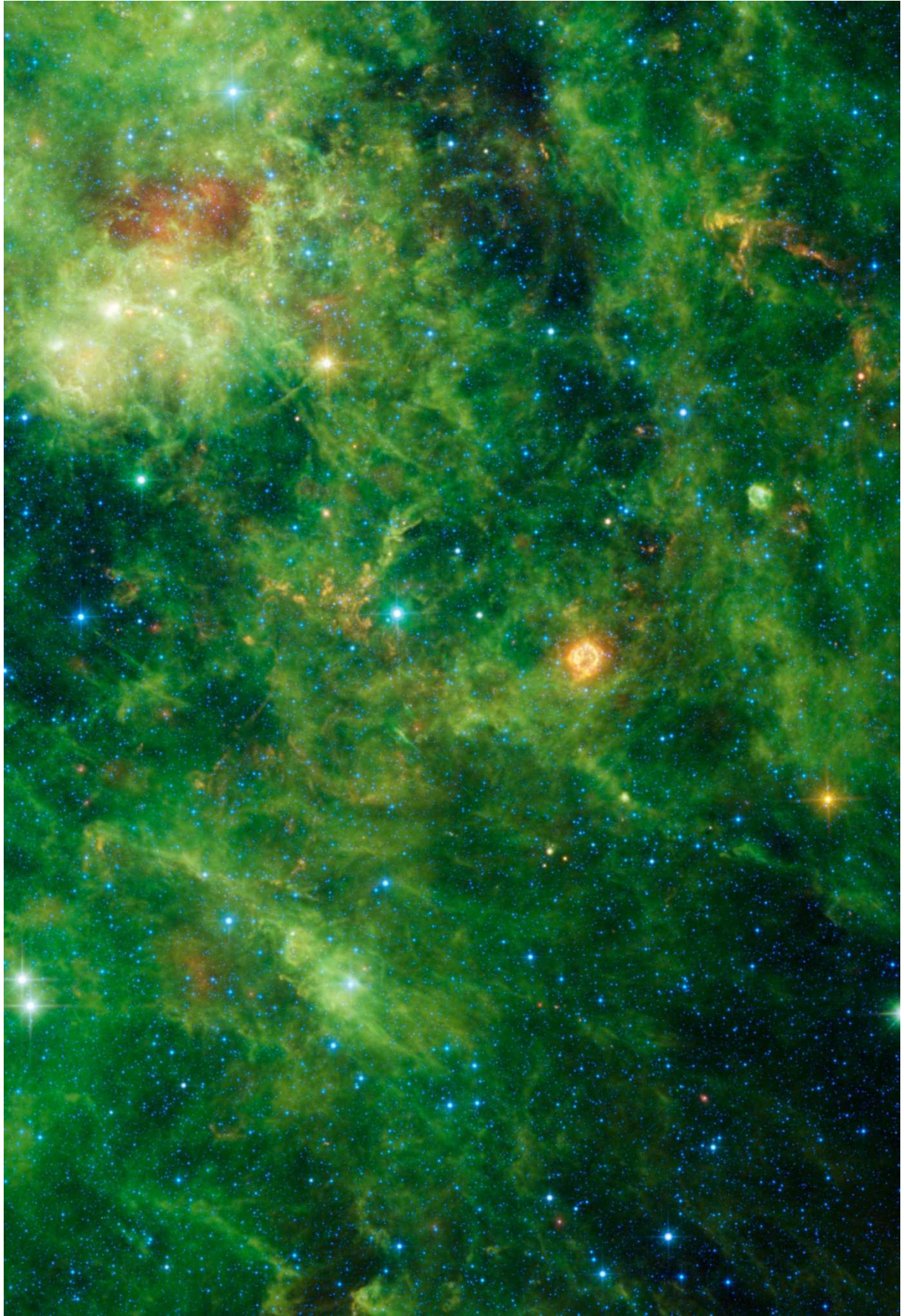
106. Imagining Apollo 13 on the Lunar Surface (Artist's Concept) (Credit: Teledyne Ryan Aeronautical)

By the time the construction of the gravity ring may be completed, the International Space Station will have its originally planned life cycle exceeded by many years, and since a Mars mission, due to its complexity, may have to spend every penny from its financial resources to be allocated for space exploration, it will not be possible to build another space station neither on low Earth orbit, nor at the Moon – moreover, the latter would also entail aborting the construction of space station Gateway planned to orbit the Moon.



107. The north pole of the Moon (Credit: NASA)

For this reason, the gravity ring connected to the International Space Station would take over the role of the International Space Station once its construction is completed. The International Space Station would be wound up, and every space station module and equipment still usable would be incorporated in the gravity ring in order to create further emergency reserves for future Mars missions on the one hand, and on the other hand, in order to be able to keep assisting scientific and commercial missions of all kinds, which the space habitat module of the gravity ring alone would be incapable of due to its limited space and capabilities.



108. Cassiopeia A supernova remnant (Credit: NASA)

Since the space station modules currently making the International Space Station do not provide any substantial radiation protection, the astronauts could only use these modules on low Earth orbit providing relative protection, and once the gravity ring would have left the gravity of the Earth, the astronauts may only stay in the space habitat module developed within the framework of Phoenix Program; however, once the lunar test programme is completed, the gravity ring would return to low Earth orbit to prepare for the Mars mission.

Returning to low Earth orbit and then leaving from the gravitational field of the Earth towards Mars may indeed entail using much more extra rocket fuel than what would be needed for leaving directly from the Moon, but many years may pass between the lunar test programme and the Mars mission, during which period, the capabilities of the gravity ring could only be exploited fully on low Earth orbit providing relative protection, and the reusable propellant carrier spaceplanes shipping several hundred tonnes of rocket fuel required for the Mars mission would also be capable of reaching low Earth orbit only.



109. NGC 1097 Spiral Galaxy in Fornax Constellation (Credit: ESA)

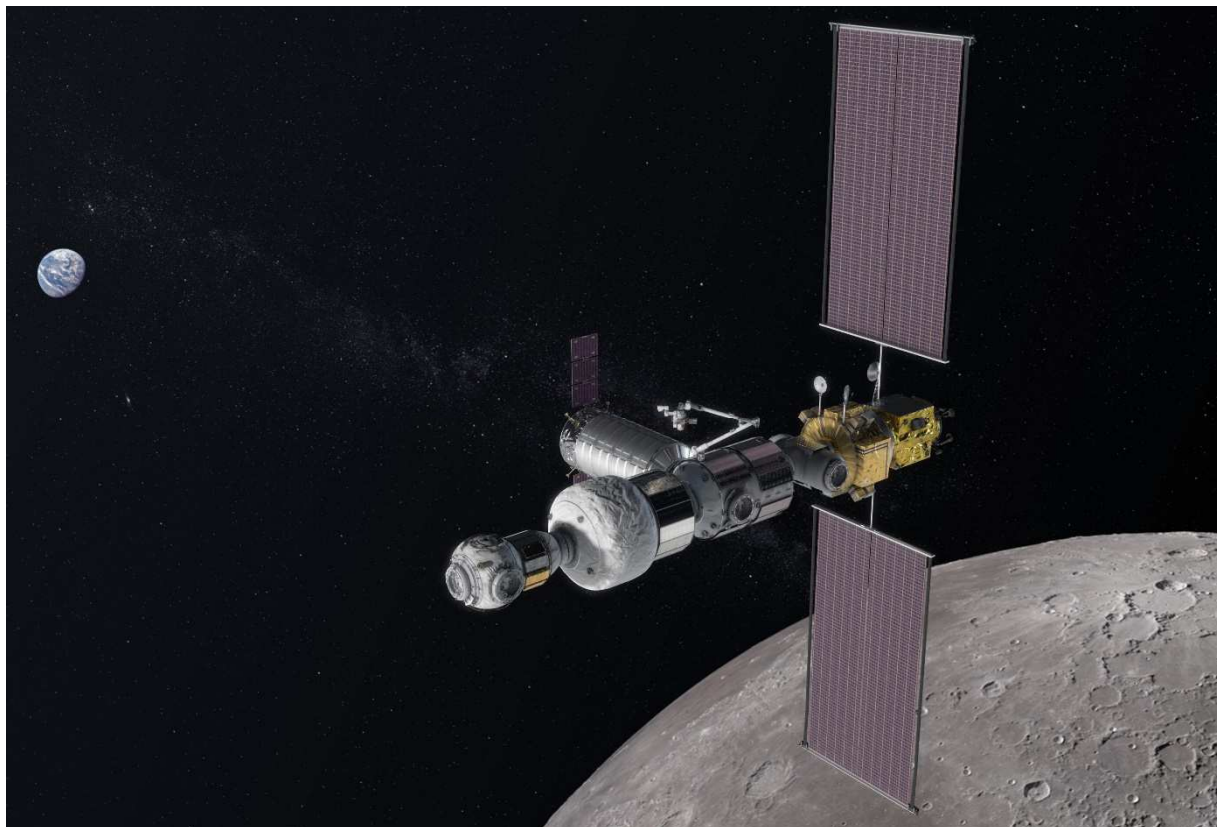
Preparations for the lunar test programme are made easier by the relatively simple and quick approach of the Moon allowing to keep minimum emergency reserves for the lunar test programme, and the only preparations to be made are the development and manufacturing of those Mars landers which will actually participate in the lunar test programme.

4.1 Orbiting the Moon

Once the construction of the gravity ring is completed, every space station module and equipment still usable would be detached from the International Space Station and relocated to the gravity ring, then the gravity ring would detach permanently from those space station modules of the International Space Station which are in bad condition and are to be demolished, and then, the remainders of the International Space Station would be moved from its orbit to make it enter the atmosphere and hit Point Nemo.

After that, the cryogenic space station module – which originally connected the International Space Station and the gravity ring under construction, and also received constant rocket fuel refills – would become a permanent part of the gravity ring, and in case the development of the NTP engine module succeeds, that would also be launched and connected to the cryogenic space station module.

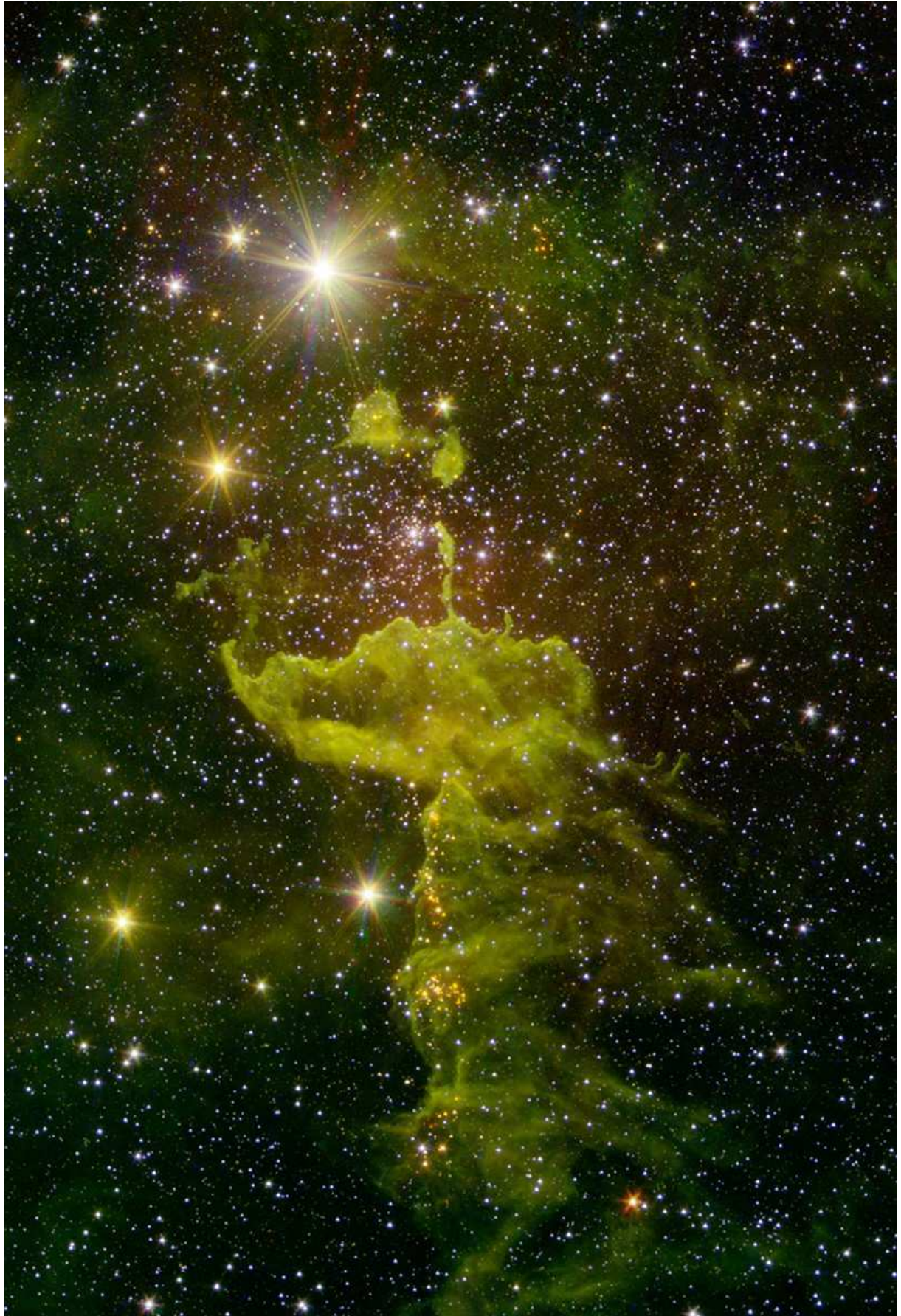
Nuclear Thermal Propulsion – unlike the traditional course correction engine module, which works by burning gaseous oxygen and hydrogen – may indeed only require liquid hydrogen as propellant, and the development of the NTP engine module would indeed simplify the acceleration and deceleration of the flight speed of the gravity ring, but the cryogenic tanks making the gravity ring would still have an emergency reserve of liquid oxygen in such amount that the chemically driven course correction engine module might need in case of a malfunction of the NTP engine module.



110. The Lunar Gateway space station (Artist's Concept) (Credit: NASA)

Once the technical service spacecraft and its reserve, the landers, the Hubble Space Telescope on low Earth orbit, as well as every other space station module, spacecraft and device required for the lunar test programme are connected to the gravity ring, the gravity ring would use its stabilisation gas distribution system to distribute liquid hydrogen and liquid oxygen rocket fuels among the cryogenic tanks making the gravity ring in order to adjust the perfect weight distribution of the gravity ring.

After this, the rotation of the gravity ring would be initiated through the manoeuvring engine modules connected to the T-shaped connectors at the ends of the spokes of the gravity ring, reaching almost two revolutions per minute required to simulate Martian gravity with artificial gravity.



111. Spider Nebula (Credit: NASA)

Once the rotation of the gravity ring is stable, an emergency test would be conducted to quickly stop the rotation, and then, all the systems of the gravity ring used for course correction and manoeuvring in deep space would be tested comprehensively, igniting every engine for a few moments at least. These tests might indeed consume lots of rocket fuel, but it is very important to know exactly how the gravity ring – draped with all kinds of things like a Christmas tree – reacts to different manoeuvres, so that the previous simulation data could be particularised with the sensory data gathered through the engine tests.

After successful engine tests, when the Earth covers the Sun and casts a shadow on the gravity ring, the gravity ring would turn over and use the thrust of the NTP engine module to achieve second cosmic velocity and escape the gravitational pull of the Earth. The gravity ring should execute this manoeuvre in the shadow cast by the Earth, because the NTP engine module, in rocket propulsion mode, would use the liquid hydrogen provided by the cryogenic space station module having its own storage capacity, and it would become unnecessary to access the large volumes of LOX/LH2 rocket fuel stored in the cryogenic tanks forming the gravity ring for acceleration, however, the shading effect of the solar panels may be cancelled by turning the gravity ring for course correction.

For this reason, the gravity ring would only use its NTP engine module for acceleration as long as it could proceed in the shadow cast by the Earth, turning its solar panels towards the Sun prior to leaving the shadow, and would also switch its NTP engine module from rocket propulsion mode to energy production mode. The gravity ring, after proceeding along an energy efficient course for a few days, would set on geostationary orbit around the Moon, above the planned location of the mission on the surface of the Moon, where the rotation simulating Martian gravity would be restarted.

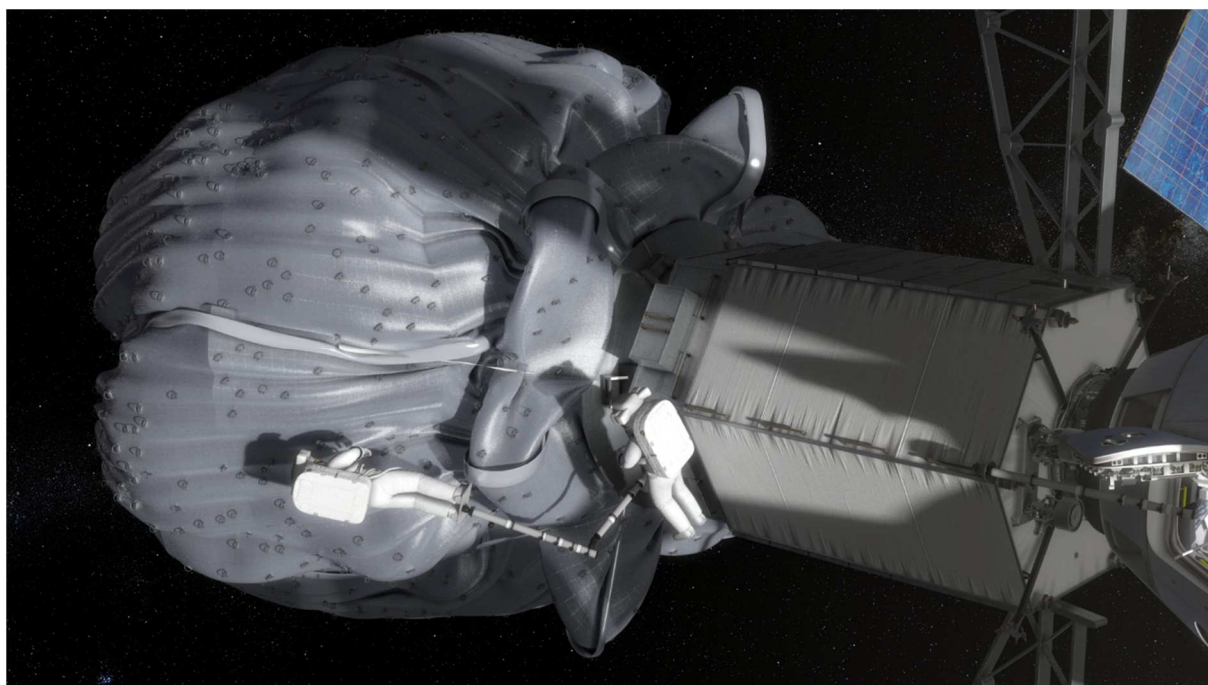


112. Boeing CST-100 Starliner spacecraft (Artist's Concept) (Credit: Boeing)

After setting on geostationary orbit, the Hubble Space Telescope connected to the gravity ring and the high-performance stereo radars would allow making 3D maps to make the mission on the surface of the Moon easier, and would also help in specifying the landing zone for the landers. The mission on the surface of the Moon by Phoenix Program would be executed in the close proximity of the Moon base of Artemis Program planned for the south pole.

4.2 Asteroid Mining

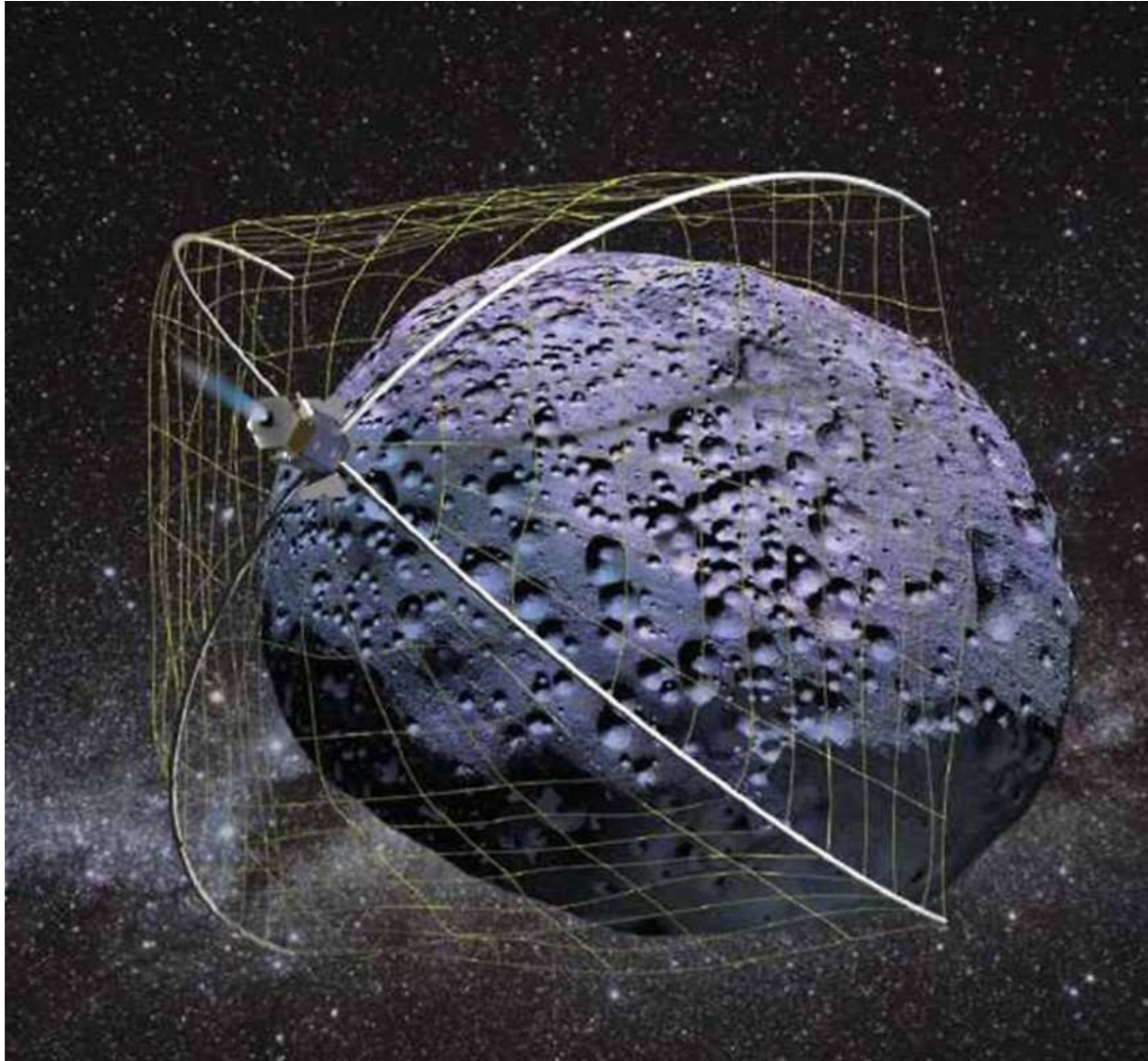
Even easily accessible near-Earth asteroids have enormous economic potential, because sending asteroids containing metals down to the Earth in an economic way would provide quasi unrestricted access to many economically critical materials from platinum to gold to rare earth elements. The so-obtained financial resources for the space industry would aid the execution of scientific deep space missions, as the technologies developed for identifying, capturing and processing asteroids in space could make it easier to solve the replenishing of rocket fuel for deep space missions.



113. Asteroid Redirect Mission (ARM) (Artist's Concept) (Credit: NASA)

This would be of particular importance in the case of Mars, because if the required technologies would be available, it would allow the two astronauts – who did not land on Mars with their fellow astronauts, but instead remained on the gravity ring on geostationary orbit above the Mars base – to make further rocket fuel reserves in the meantime by partly processing a near-Mars asteroid and so reducing the time required for returning to the Earth after completing the mission on the surface of Mars. For this reason, Phoenix Program would revive Asteroid Redirect Mission (ARM) of NASA.

After selecting the ideal near-Earth asteroid, a robotic spacecraft would move to the chosen asteroid and release a thin metal mesh in its close proximity, allowing the asteroid to fly into this mesh. After this, the robotic spacecraft would land on the surface of the asteroid by drawing together the ends of the metal mesh. This metal mesh would be a light structure with minimum load-bearing capacity, and would not change the course of the asteroid, but would primarily allow to connect the asteroid to the robotic spacecraft firmly.

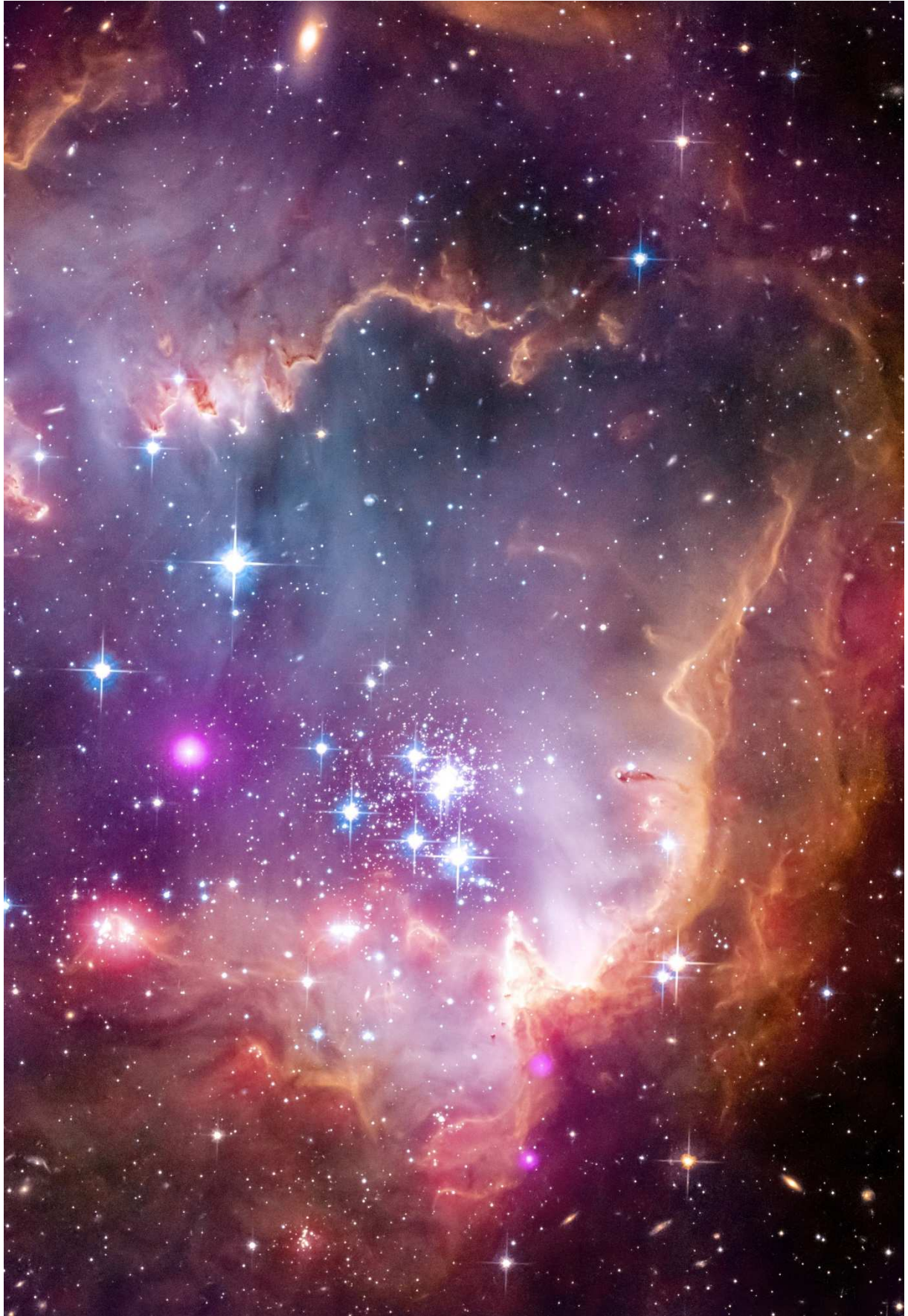


114. Weightless Rendezvous And Net Grapple to Limit Excess Rotation (WRANGLER) System (Artist's Concept) (Credit: NASA)

Once the robotic spacecraft has landed on the asteroid covered with the thin metal mesh, a separate robotic vehicle would detach from the spacecraft. Essentially, this robotic vehicle would be a manoeuvring rocket engine moving with spider legs, having a constant connection with the robotic spacecraft through a flexible pipeline. Through this pipeline, the robotic spacecraft could constantly provide the robotic vehicle with energy and monopropellant.

The spider legs would allow the robotic vehicle to hang onto the metal mesh stretching along the surface of the asteroid, and move safely along the surface of the asteroid – having a diameter no more than ten metres –, without falling off accidentally due to the absence of gravity.

This robotic vehicle, acting as a manoeuvring rocket engine, would perform the course corrections of the asteroid to reach high lunar orbit. As the chosen near-Earth asteroid could rotate uncontrollably around all three axes, the robotic vehicle, in order to reach high lunar orbit, may have to use its manoeuvring rocket engine at up to half a dozen different spots along the surface of the asteroid, and the robotic vehicle could reach these spots one after another by hanging onto the metal mesh using its spider legs.



115. Small Magellanic Cloud (Credit: NASA)

In order to allow the robotic vehicle to pass on the thrust – generated by its manoeuvring rocket engine upon ignition – to the asteroid, and also to be able to remain connected firmly to the surface of the asteroid in the meantime, the robotic vehicle – beyond its thin spider legs to be used for moving, hanging and positioning – would also be provided with wide, foldable stabiliser footings.

Since – depending on the original course of the selected near-Earth asteroid – several months may pass until it reaches the Moon after the course corrections and sets on high lunar orbit by exploiting the Moon's gravity, the robotic vehicle would use the tremendous amount of time available and the rocket fuel – remaining after the course corrections executed for reaching the Moon – to stabilise the rotation of the asteroid as much as possible in order to make it easier for the astronauts to visit the asteroid.

Since the gravity ring, by this time, would already be on geostationary orbit above the planned location of the mission on the surface of the Moon for the sake of the lunar test programme, the astronauts could easily approach the asteroid when it is setting on high lunar orbit using the technical service spacecraft.



116. An astronaut retrieving a sample from the captured asteroid (Artist's Concept) (Credit: NASA)

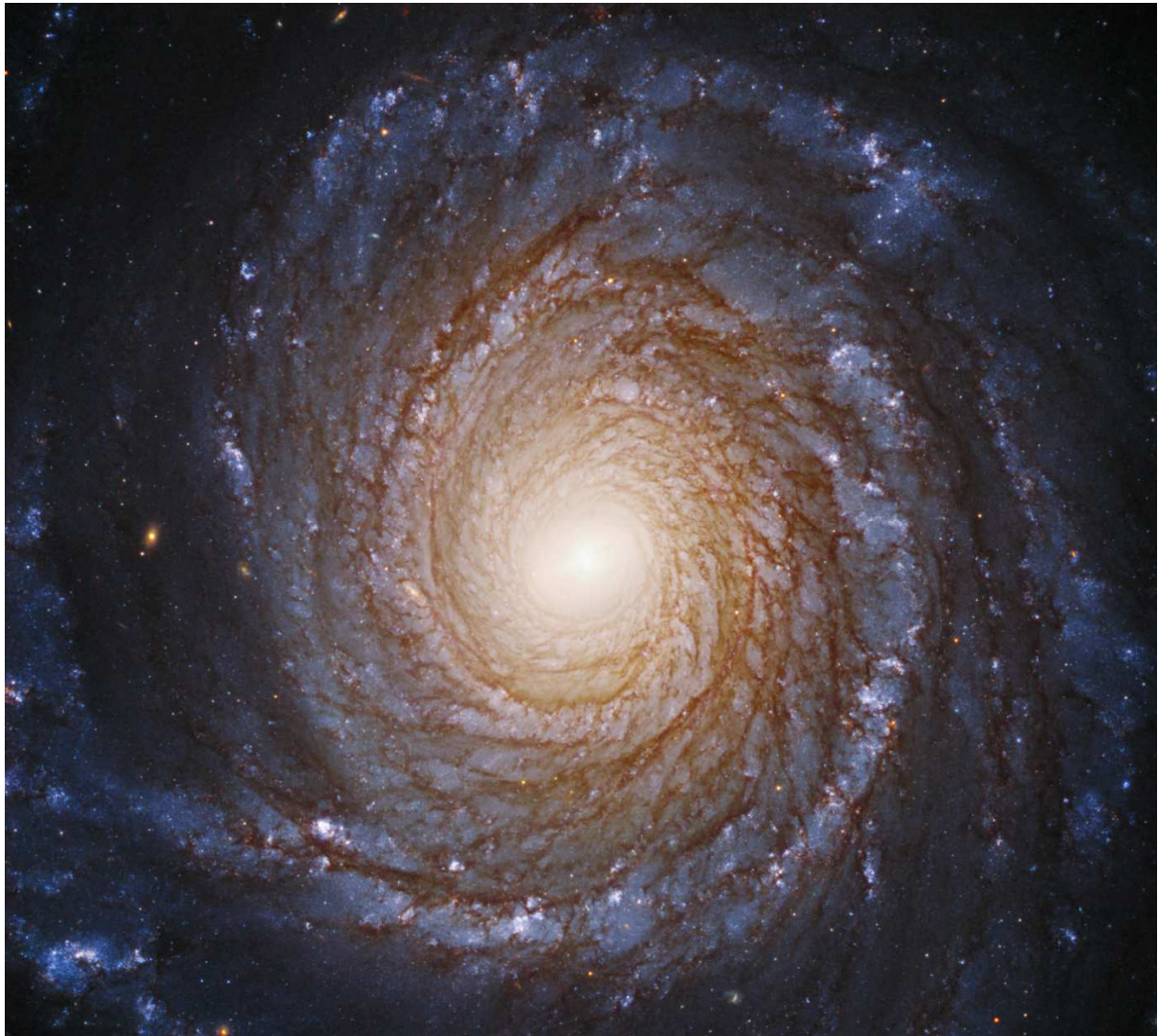
Once samples have been collected from the surface of the asteroid, the astronauts would fix a dozen of manoeuvring rocket engines – similar to the spider-legged robotic vehicle – scattered across the surface of the asteroid, which would also be connected to the robotic spacecraft using pipelines, and after refuelling the rocket fuel tanks of the robotic spacecraft, the astronauts would use the technical service spacecraft to return to the gravity ring.

By installing further manoeuvring rocket engines, the course of the asteroid on high lunar orbit could be changed freely, allowing to remotely manoeuvre the asteroid in the close proximity of the gravity ring, within the range of the Manned Manoeuvring Unit (MMU) connected to the spacesuit of the astronauts. With this, the captured asteroid, having a significant weight despite its diameter of no more than ten metres, would be far enough from the gravity ring not to pose any risk to its structure,

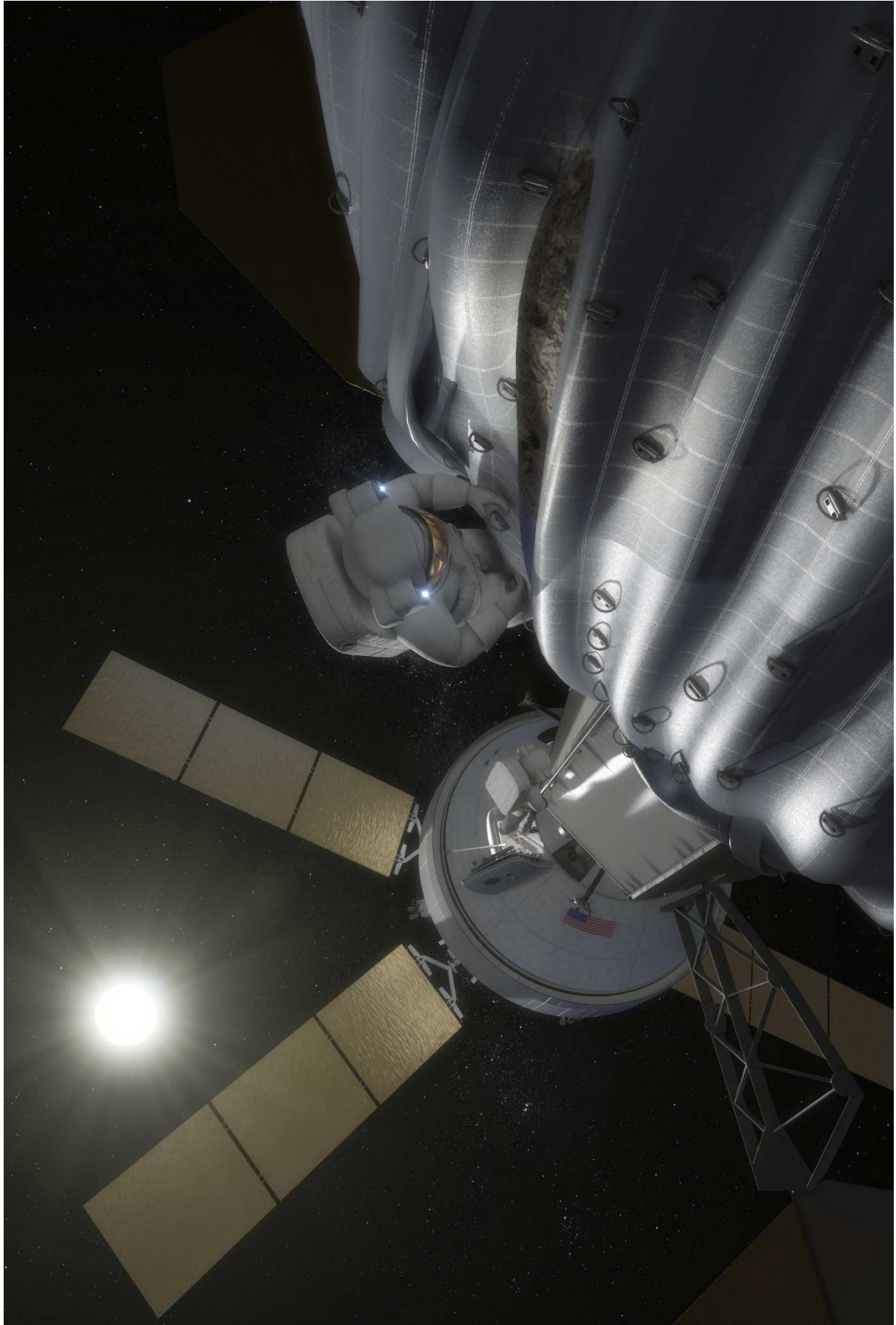
and would also be close enough to allow the astronauts to perform sufficiently thorough examinations easily and safely regarding the in-space processability of the asteroid.

Once the exact material composition of the asteroid has been specified, the astronauts would once again return to the asteroid using the technical service spacecraft to drill a hole with a length of no more than half a metre into the surface of the asteroid, placing a safety dome above the planned location of the hole to contain debris breaking loose when drilling. This safety dome would be open on the top until the drill head is inserted, while the drilling equipment could be fixed to the end of one of the Canadarm robotic arms of the technical service spacecraft.

Once the drilling is completed, a heavy-duty clamping handle would be installed in this hole, allowing the technical service spacecraft to grip firmly onto this metal clamping handle using its other Canadarm robotic arm for further works on the asteroid. This would make working on the asteroid much safer, and the drilling equipment used for the first drilling could be used to start drilling deeper into the asteroid. Before starting a new drilling, the astronauts would place another safety dome to contain debris.



117. Spiral galaxy NGC 3147 in constellation Draco (Credit: NASA)



118. Astronaut preparing to take samples from the captured asteroid (Artist's Concept) (Credit: NASA)

After another drilling of the asteroid with a length of no less than two metres, the astronauts would place a mining module above the new hole and insert a liner rod protruding by no less than two metres from the front of the mining module into the drilled hole. This liner rod would be developed on the basis of the technology of the inflatable space station modules of Bigelow Aerospace and would also be provided with the modules' Vectran covering material, so that once the mining module is placed and the liner rod is inflated, the rod's flexible material would settle very strongly to the inner wall of the hole drilled into the asteroid in a length of two metres.

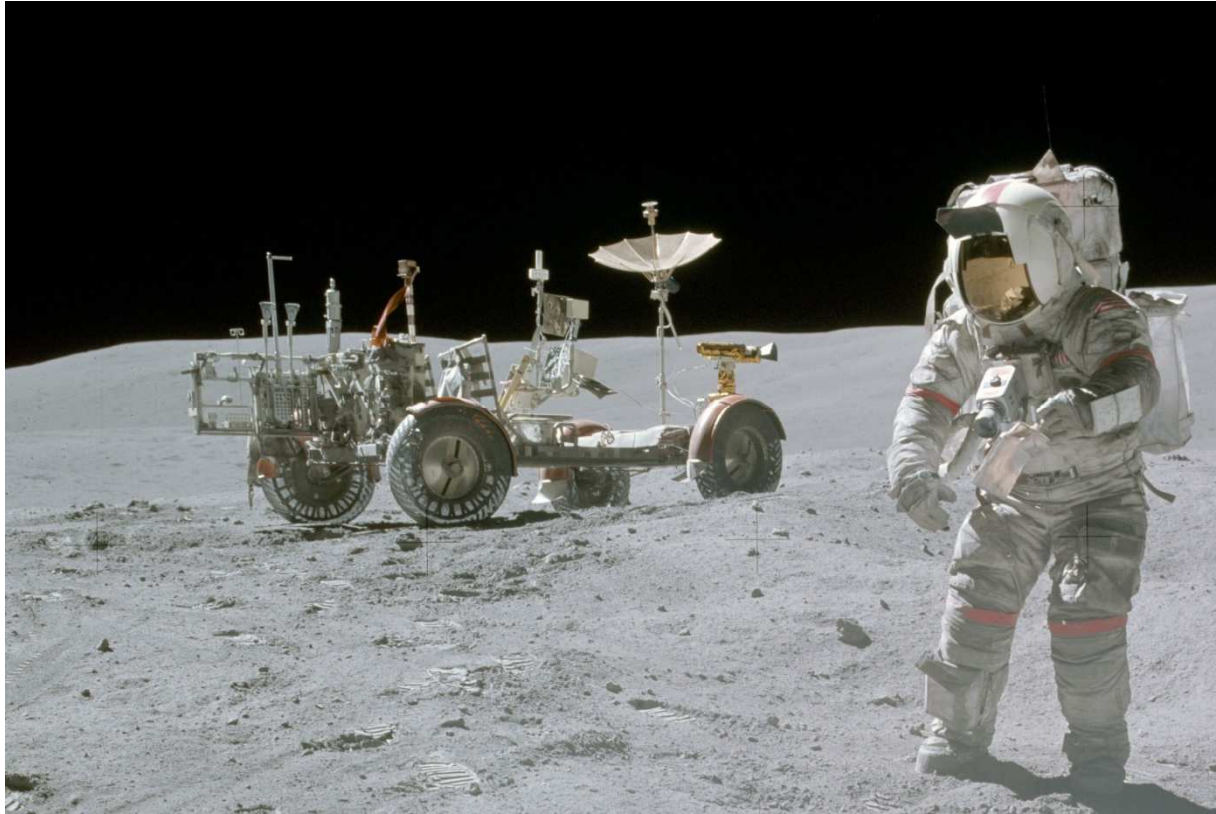


119. Apollo 15 rover on the Moon (Artist's Concept) (Credit: Teledyne Ryan Aeronautical)

Using the liner rod, on the one hand, would allow fixing the mining module firmly to the asteroid, and on the other hand, would allow to infuse compressed helium into the hole drilled in the asteroid, turning the hole into a pressurised space, making an environment of helium inside the asteroid with a pressure of several atmospheres.

Then the NTP engine module and the cryogenic space station module would be detached from the gravity ring and then would be connected to the mining module using the Canadarm robotic arms of the technical service spacecraft. The mining module would use electrically generated laser to evaporate the material of the asteroid through the hole drilled into the asteroid, starting from the inside; the required energy would be supplied by the NTP engine module set to operate in energy production mode.

Since the reactor of the NTP engine module in energy production mode would be cooled by the cryogenic space station module using its own large volumes of helium stored in liquid state, the two modules would remain connected to one another all along, from being detached from the gravity ring to being relocated to the mining module.

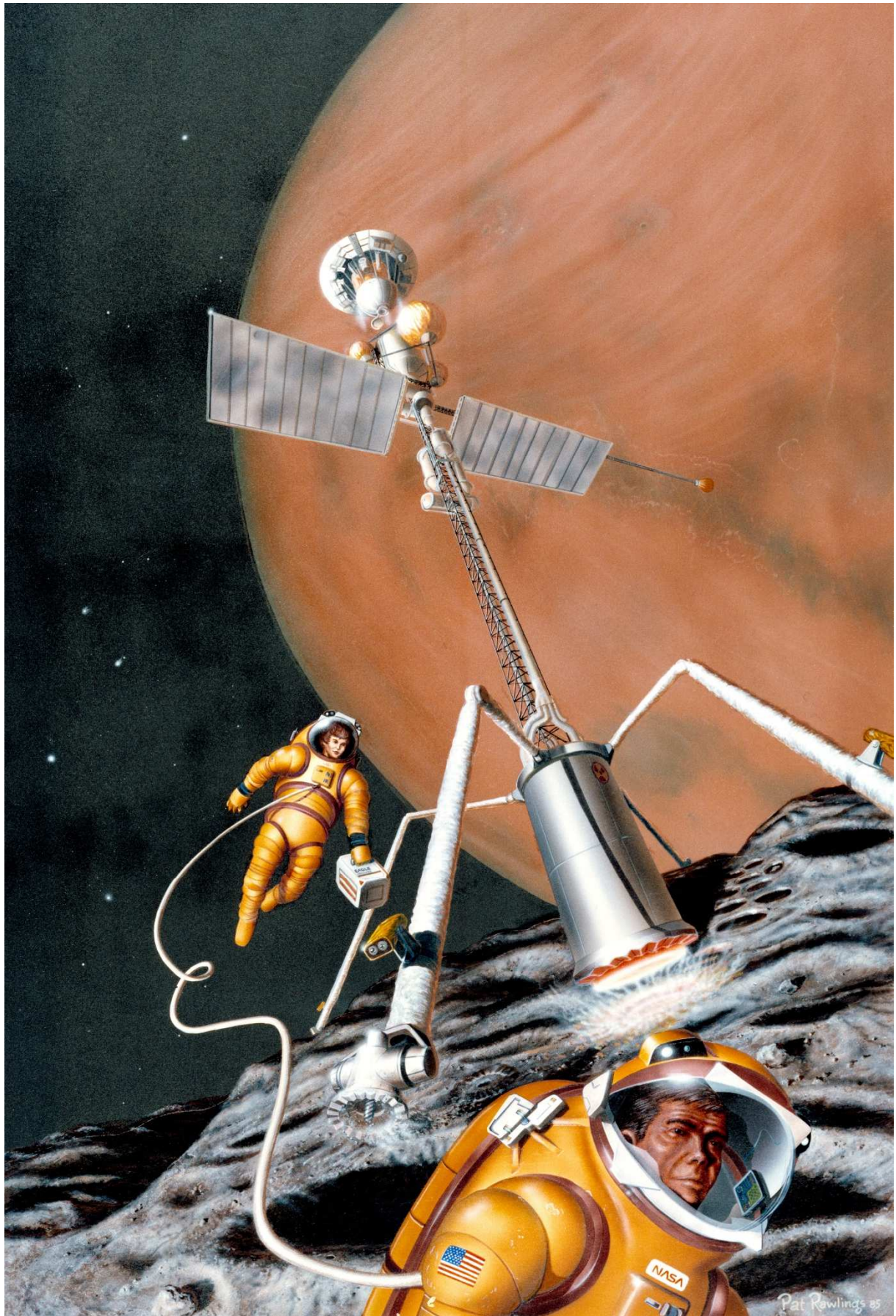


120. Apollo 16 astronaut John Young collecting samples at North Ray crater (Credit: NASA)

The gas required for creating the high-pressure helium atmosphere inside the asteroid would also be provided by the cryogenic space station module. Throughout this process, the cryogenic space station module, having the NTP engine module and the mining module attached, would constantly circulate gaseous helium towards the asteroid by firstly heating it to several hundred degrees Celsius through one of the heat exchangers connected to the reactor of the NTP engine module, making it easier for the high-performance laser of the mining module to evaporate the material of the asteroid.

The cryogenic space station module would use cryogenic distillation technology to separate the components of the gas pumped out from the inside of the asteroid, allowing the different materials making the asteroid to be stored in separate tanks, which the astronauts could carry to the gravity ring through a spacewalk for analysis, inspection, or even preparing the materials to be shipped to the Earth.

As helium liquefies at the lowest temperature out of all the chemical elements, the high-pressure helium atmosphere could be sustained constantly inside the asteroid, without the need to liquefy the gaseous helium again after separating the materials making the asteroid using cryogenic distillation.



121. A mobile propellant-production plant with nuclear reactor on Phobos (Artist's Concept) (Credit: Pat Rawlings)

Since the partial processing of the captured asteroid would take place in the close proximity of the gravity ring, and the astronauts might have to take many spacewalks even for the preparations of the mission on the surface of the Moon, the asteroid would already be rotated in such a way compared to the gravity ring that the asteroid itself could provide shading against radiation, decreasing radiation exposure imposed on the astronauts by the reactor of the NTP engine module.

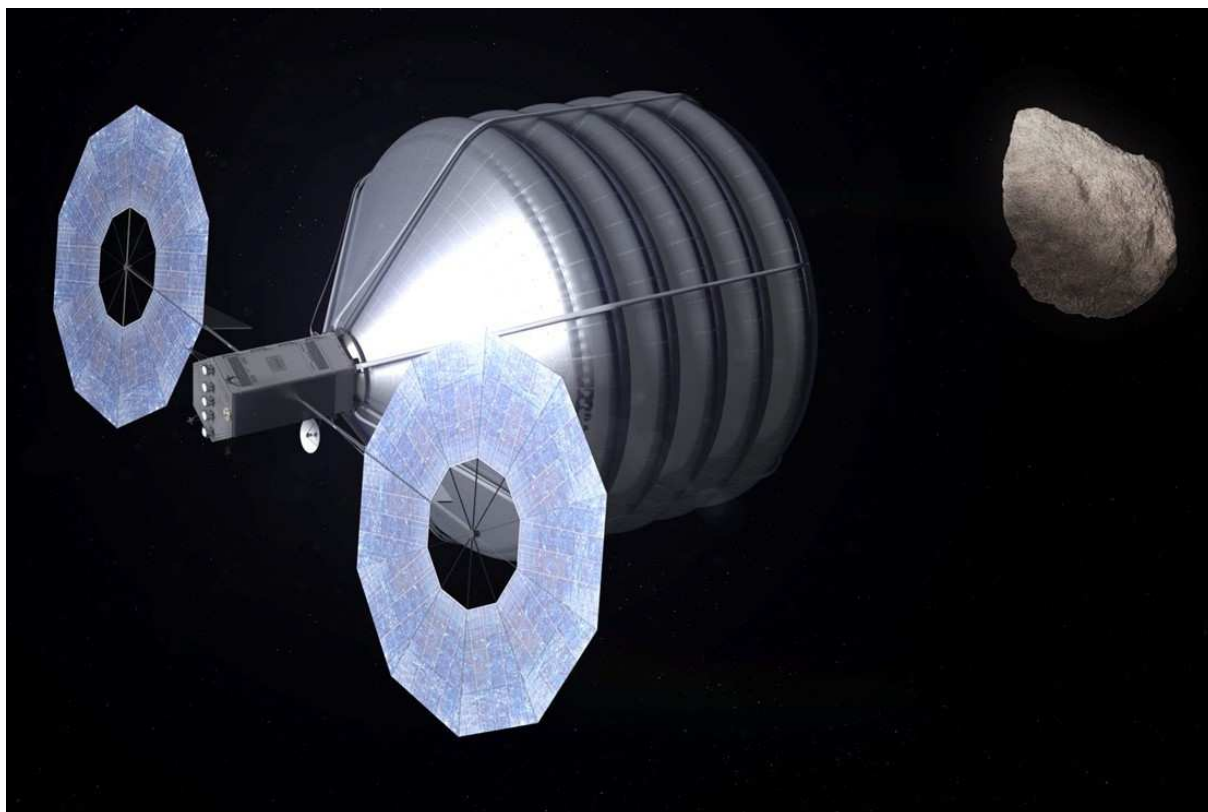
Once the asteroid mining experiment is completed and the helium is pumped out of the asteroid, the NTP engine module and the cryogenic space station module – which make one structural unit – would be reconnected to their original place on the gravity ring with the help of the technical service spacecraft. The liner rod inserted into the hole drilled in the asteroid would be interchangeable, allowing to detach the mining module from the asteroid without the need to remove the liner rod from the hole.



122. Multi-dome lunar base being constructed (Artist's Concept) (Credit: ESA)

Since the mining module would use electrically generated laser provided constantly with energy by the reactor of the NTP engine module, any number of asteroids could practically be processed partially, one after another, using a single mining module.

At the same time, however, using this type of mining module would always allow to process the chosen asteroids partially only, because only such amount of material could be evaporated and obtained from the inside which would not pose any risk of leakage to the helium atmosphere created inside the asteroids. For the complete processing of an asteroid stabilized by the manoeuvring rocket engines, the entire asteroid should be covered with a pressurised casing – instead of drilling the asteroid and using a liner rod inside –, which could be solved easily in case of an asteroid with a diameter of a few metres only, but could be complicated in case of an asteroid with a diameter of more than a hundred metres.



123. Asteroid capture (Artist's Concept) (Credit: NASA)

In case producing LOX/LH2 rocket fuel or any component thereof throughout the asteroid mining experiment performed on lunar orbit were to succeed, one or more smaller near-Mars asteroids would be selected for Phoenix Program, and would be captured and carried to high Mars orbit using robotic spacecrafts by the time the astronauts reach Mars.

4.3 Planet Protection

The Earth currently has no genuine protection against asteroids as the budget and technical equipment of NASA, ESA, JAXA and the other space agencies are sufficient to detect only a fraction of the asteroids posing a risk to the Earth, and oftentimes, such asteroids are detected only a few hours prior to entering the atmosphere of the Earth.

However, involving financial resources in asteroid mining would also allow improving the protection of the Earth against dangerous asteroids, because essentially the same technologies are needed to be developed for finding asteroids for mining purposes and redirecting the selected asteroids to the location of processing what we need for a more efficient protection of our planet.

On the same principles as NASA DART mission, the asteroids selected and captured for the asteroid mining experiment of Phoenix Program could be used easily for the impact redirection of relatively small astronomical objects – such as near-Earth minor planets like Bennu – by exploiting the manoeuvring rocket engines installed to the captured asteroids, even if such objects may pose a direct risk to the Earth only decades or centuries later. Thanks to the decades or centuries available, the impact energy of these captured asteroids – with a diameter no more than ten metres – could be sufficient to change the course of asteroids that may pose a risk to the Earth.



124. Double Asteroid Redirection Test (DART) (Artist's Concept) (Credit: NASA)

In case of a minor planet with a diameter of several kilometres and where only a little time is available for redirection, the threat could only be prevented through a nuclear explosion; that, however, could not be executed on the surface of the minor planet, because even if most of the original weight of the minor planet could be redirected and set on a different course, a debris cloud of the pieces of the original minor planet – each piece having a diameter of several hundred metres – would still pose a serious risk to the Earth.

In case this nuclear explosion were to occur merely a few hundred metres from the minor planet, basically, only the X-rays of the nuclear explosion would affect the minor planet due to the vacuum of space, and opposing forces created by the evaporation of the materials on the surface of the minor planet due to the intensive X-rays would only result in a slight redirection of the minor planet.

However, installing the nuclear warhead into the hollow inside of an asteroid that has already been processed partially through asteroid mining, and manoeuvring this asteroid carrying the nuclear warhead near the dangerous minor planet to detonate the nuclear warhead only a few tens of metres from the dangerous minor planet would allow to exploit most of the forces resulting from the nuclear explosion, as the shock-wave caused by the instant evaporation of the high-pressure gas resulting from the explosion of the asteroid would also affect the dangerous minor planet.

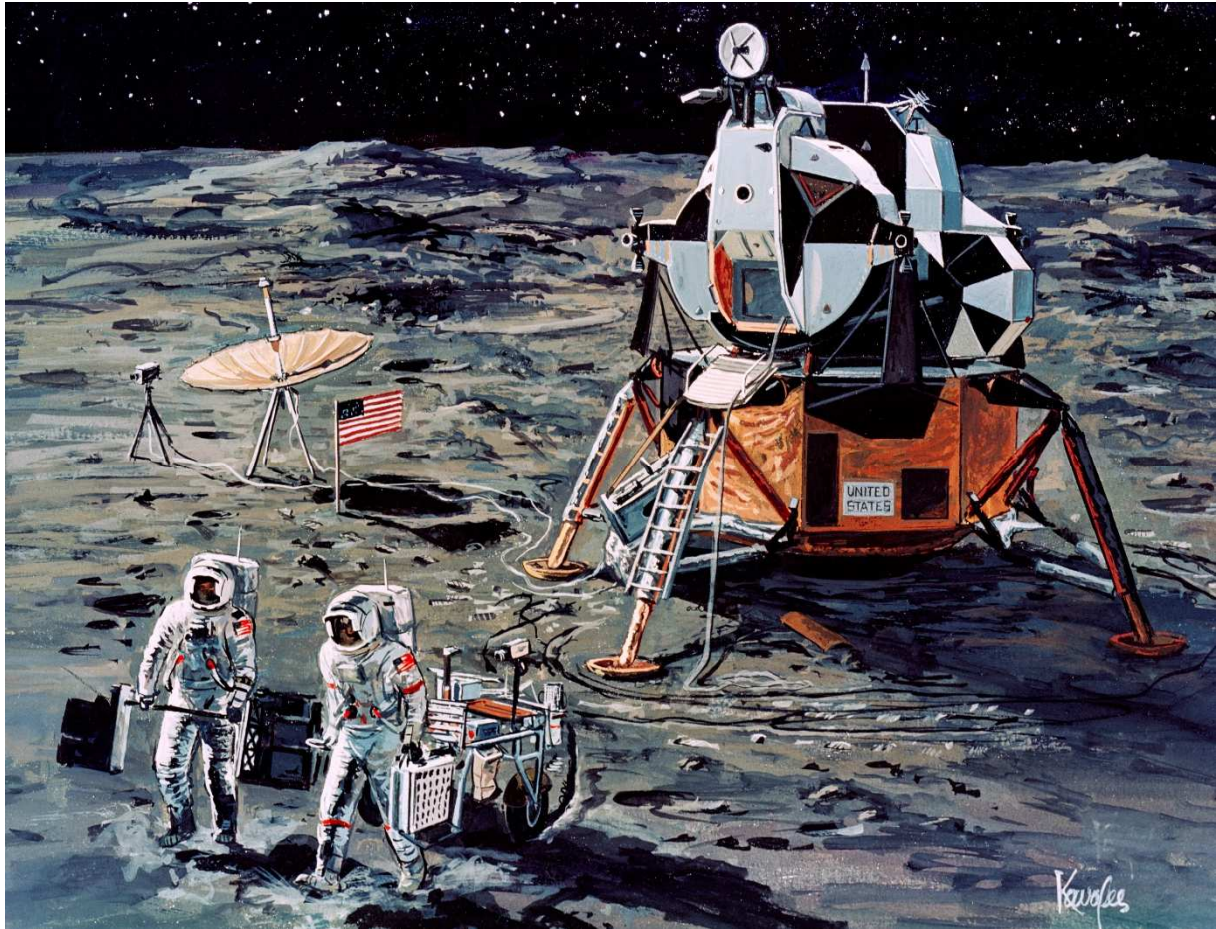
4.4 Collecting Samples from the Moon

Since the tests of Phoenix Program carried out at the Moon – unlike Artemis Program – would explicitly be the “dress rehearsals” for the Mars mission in respect of both the gravity ring and the landers, the landers used for the lunar test programme would be the same as the landers of the Mars mission.



125. Apollo 14 Command and Service Modules circling the Moon (Artist's Concept) (Credit: NASA)

First of all, two completely refuelled propellant shuttles would leave the gravity ring on the geostationary orbit of the Moon and land in the landing zone, in the close proximity of the Moon base of Artemis Program (Artemis Base Camp). Next, a Mars exploration vehicle and a shelter base module would land, after the successful landing of which, a Mars shuttle with two astronauts on board would also land on the surface of the Moon.



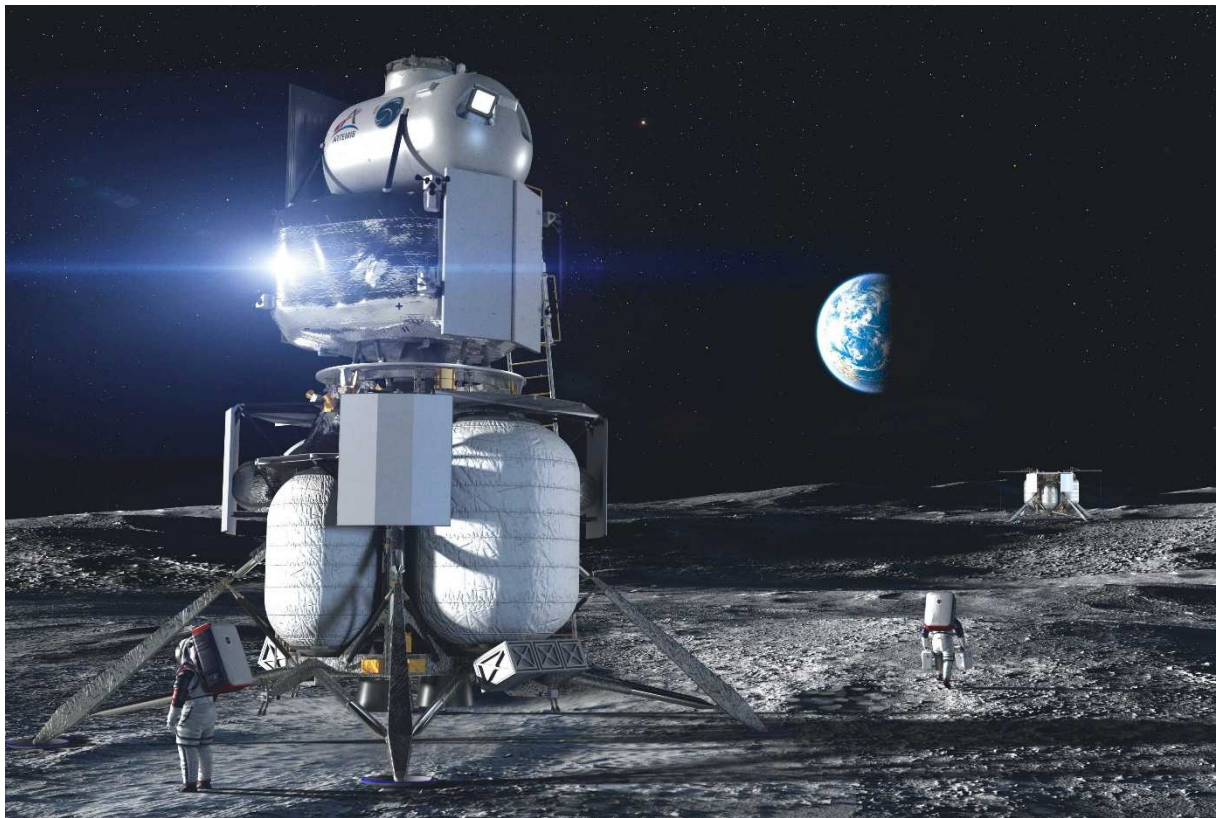
126. Apollo 14 crewmen on the lunar surface (Artist's Concept) (Credit: Grumman Aerospace Corporation)

Since the Moon has no atmosphere, the Mars shuttle used for the lunar test programme would be redesigned: the crew module would not be provided with a heat shield and supersonic parachutes, and the service module would not be provided with disposable primary heat shield either, allowing the Mars shuttle to ignite its main LOX/LH₂ rocket engines instantly when landing is started. In the absence of atmospheric friction, the shelter base module, the exploration vehicle and the two propellant shuttles would not be provided with heat shield for the lunar test programme.

The landers could provide their ATHLETE robotic legs with energy from their own fuel cells when landing in the Shackleton crater on the surface of the Moon, allowing the landers to go to Artemis Base Camp after landing by controlled remotely. As the mission on the surface of the Moon of Phoenix Program would take place in the close proximity of Artemis Base Camp, the astronauts would have much more opportunity to solve any issues in case of an emergency, and the equipment of Artemis Program could serve as emergency reserves for the mission on the surface of the Moon of Phoenix Program.

Once every lander had reached Artemis Base Camp, the astronauts would put on their xEMU spacesuits in the extremely tight pressurised habitat of the crew module of the Mars shuttle, and then, after degassing the crew module of the Mars shuttle, the astronauts would leave through the large pressure-tight openings on the side one after another. As the Mars shuttle would originally be designed for transporting four astronauts, the xEMU spacesuits – requiring a considerable amount of space – could be placed on the two empty seats of the crew module.

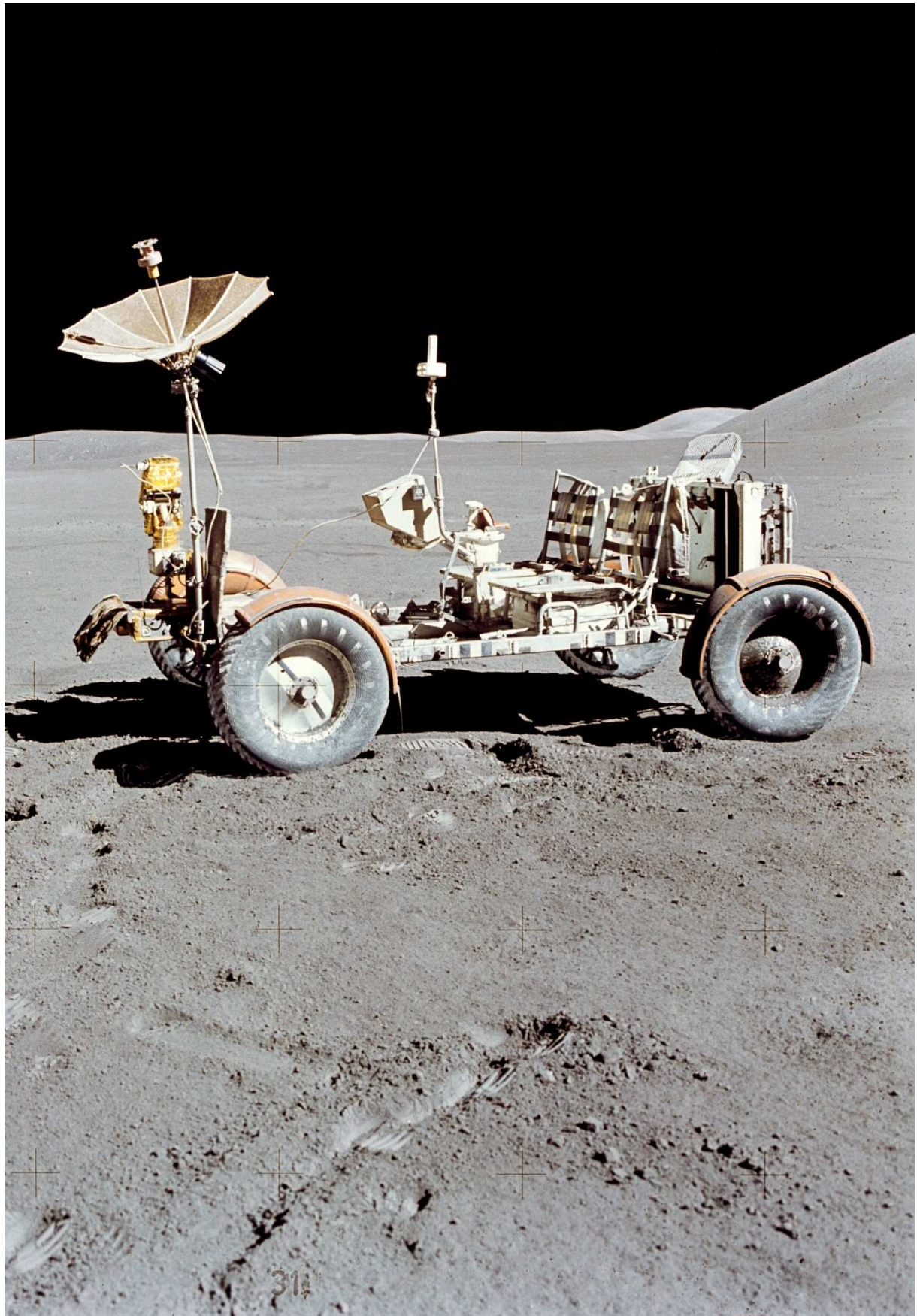
The opening on the side of the crew module of the Mars shuttle would be located rather high above the surface of the Moon due to the service module below, and for this reason, the astronauts would use one of the ATHLETE robotic legs of the Mars shuttle – which could be rotated in any direction – to reach the surface of the Moon; the astronauts would stand on the end of the robotic leg, which would act as a moving ramp to take them down to the surface.



127. The Blue Origin National Team crewed lander on the surface of the Moon (Artist's Concept) (Credit: Blue Origin)

One of the equipment of the crew module of the Mars shuttle would be a telescopic ladder, which could be fixed with two dedicated fixing points to a panel on the outer casing located directly next to the opening, providing the astronauts standing on the ATHLETE robotic leg with a handrail as well. Since there is no atmospheric friction when landing on the Moon, this telescopic ladder, unlike in the mission on the surface of Mars, would already be fixed to the side of the Mars shuttle before landing on the Moon.

The astronauts leaving the Mars shuttle in their xEMU spacesuits would release the fixing clamps on the outer casing of the exploration vehicle and of the shelter base module, and would initiate the inflation of the donut-shaped secondary habitats of the two landers containing, among others, the airlocks as well.

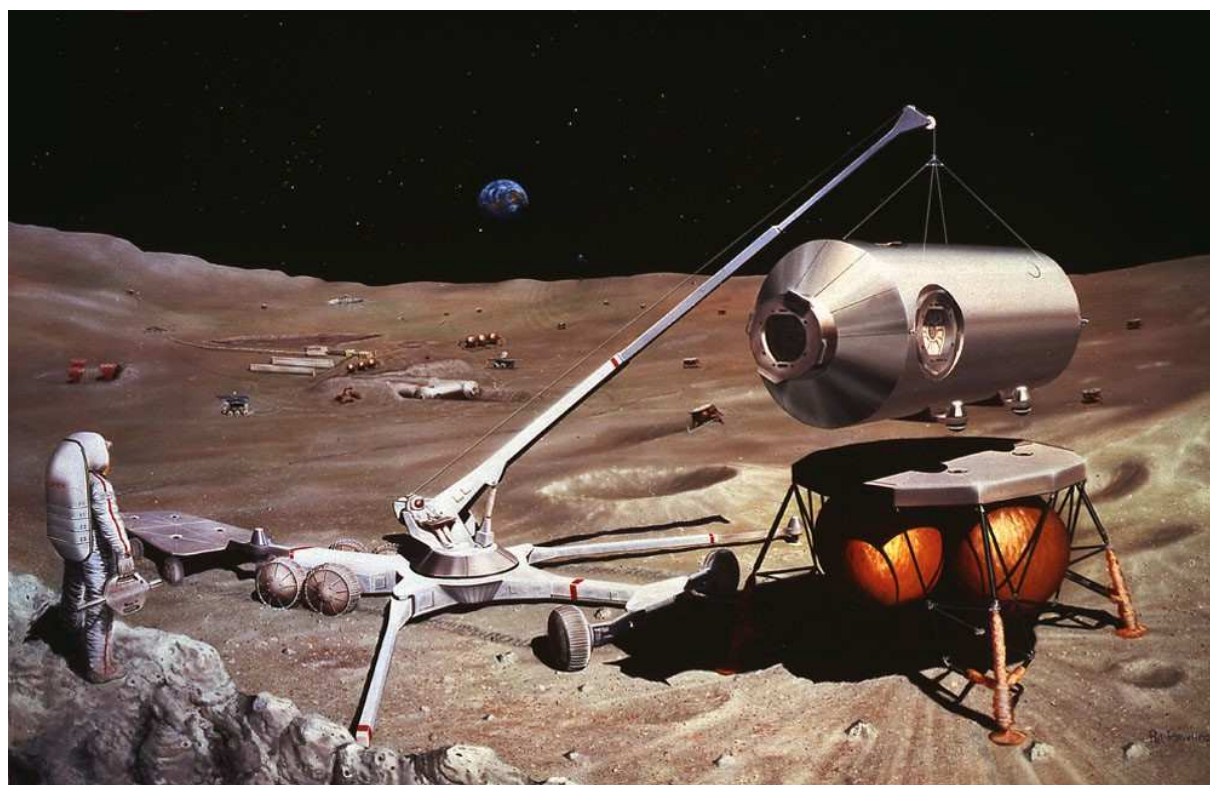


128. Lunar Roving Vehicle (Credit: NASA)

As soon as the secondary habitats are inflated, the astronauts, wearing spacesuits polluted heavily with lunar dust by now, would enter the exploration vehicle through the docking ports dedicated for xEMU spacesuits. The astronauts would be able to use the exploration vehicle before putting its wind tunnel in use thanks to these xEMU spacesuits docking ports.

Since one of the basic features of the Mars exploration vehicle would be the ability to drift away from the bases established, the passenger compartment of the exploration vehicle would also be provided a chemical lavatory which could only be used in an environment with gravity, allowing the astronauts to take a longer rest in the passenger compartment of the exploration vehicle before proceeding with their duties.

After this, the astronauts would control the two propellant shuttles and the Mars shuttle remotely from the passenger compartment of the exploration vehicle to accurately level those using their ATHLETE robotic legs, taking the position of their fixing points into consideration, and then would connect the two propellant shuttles to the Mars shuttle, preparing those to be able to take off at any time in case of an emergency.



129. Lunar Crane (Artist's Concept) (Credit: Pat Rawlings)

Two completely refuelled propellant shuttles would aid the completely refuelled Mars shuttle in taking off, however, since the gravity of the Moon is approximately only a sixth of the gravity of the Earth, and atmospheric friction should not be taken into account upon lift-off either, only those two propellant shuttles would participate in the mission on the surface of the Moon which aid the Mars shuttle in taking off – in contrast to the Mars mission.

At the same time, however, since landing on the Moon requires much less rocket fuel than landing on the surface of Mars due to smaller gravity, and therefore a significant amount of LOX/LH2 rocket

fuel would remain in the exploration vehicle and in the shelter base module after landing, the Mars shuttle and the two connected propellant shuttles could practically be refuelled completely, even though no further propellant shuttles would arrive on the surface of the Moon.

In order to pump liquid hydrogen and liquid oxygen from the exploration vehicle and the shelter base module into the propellant shuttles and the Mars shuttle, the astronauts would take another spacewalk in their xEMU spacesuits through the docking ports of the exploration vehicle, and connect the landers using the dedicated, flexible, multi-purpose charging cables and the resource-distribution connectors. These flexible charging cables, each having a length no less than twenty metres, would be stored in the tool- and equipment storage room of the exploration vehicle due to their large space requirements, allowing the astronauts to access these cables immediately after inflating the secondary habitat of the exploration vehicle.



130. Lunar expedition (Artist's Concept) (Credit: NASA)

Once the cryogenic rocket fuel tanks of the exploration vehicle and of the shelter base module are depleted, allowing to use their liquid hydrogen tanks as primary habitat, the astronauts could start unpacking and checking the pre-packaged equipment of the secondary habitats of the two landers. For this, the astronauts would connect an airlock of the exploration vehicle with an airlock of the shelter base module, thus establishing a smaller Moon base.

Since the exploration vehicle and the shelter base module would not be able to produce energy with their fuel cells after depleting their cryogenic tanks, the astronauts would use an electric cable to connect the shelter base module with Artemis Base Camp – as the distance between these would be no more than a few dozen metres –, allowing the solar panels of Artemis Base Camp to act as primary power supplies for the landers.



131. Apollo 11 astronaut Buzz Aldrin at Lunar Module Eagle in Tranquility Base (Credit: NASA)

The back-up power supply would be provided by the fuel cells of the propellant shuttles, but some foldable solar panels would also be among the pre-packaged equipment in the shelter base module in order to be prepared for any emergency; the astronauts could fix these foldable solar panels to a simple, on-site-assembly, tubular metal structure, which could then be fixed to the side of the shelter base module like as a sail. The size and power capacities of these solar panels would not be enough to supply all the landers with power, and so these solar panels would only act as a minor emergency power supply.



132. Activities in a Moon Base (Artist's Concept) (Credit: ESA)

The shelter base module of Phoenix Program would be intended to act as the possibly safest rest area protecting against cosmic ray and charged particles of solar flares both on the surface of the Moon and Mars. For this purpose, a shelving would be assembled in the cryogenic tanks serving as the primary habitat when furnishing; this shelving would occupy the habitat practically to the fullest extent, leaving only a narrow gangway between the two pressure-tight doors of the cryogenic tank.

The structure of this shelving would allow to establish a sleeping accommodation separated with a curtain for each astronaut, and every remaining square centimetre of the shelving could be used as a storage for water, foodstuff, clothes and other equipment, as well as for different tools.

This would allow the outer casing of the shelter base module to protect the resting astronauts, and the casing of the cryogenic tanks used as primary habitat to protect the large amounts of stored equipment against cosmic ray; the latter would also allow the astronauts to spend an extended period of time in the relatively safe cryogenic tank in case of a really strong solar flare and use the supplies stored therein.

The inflated donut-shaped secondary habitat of the shelter base module with airlocks would also be equipped with a lavatory – which could only be used in an environment with gravity – and a related water recycling device as well, the water tank of which would be installed above the cryogenic tank in the shelter base module used as primary habitat, which would provide yet another radiation-absorbing layer to mitigate the radiation exposure of the resting astronauts.



133. Apollo 17 astronaut Eugene Cernan drives the Lunar Roving Vehicle (Credit: NASA)

Throughout the mission on the surface of the Moon, the depleted liquid oxygen tanks of the shelter base module and of the exploration vehicle would act as large volume emergency air tanks for the astronauts, as no constant oxygen supply would be available on the Moon due to the absence of a nuclear supply module producing oxygen from the atmosphere – unlike in the case of the mission on the surface of Mars.

Since the Moon has no atmosphere, the wind tunnel of the exploration vehicle could only be operated with this emergency air supply, and for this reason, the astronauts would minimise the use of the dedusting wind tunnel throughout the mission on the surface of the Moon, using the xEMU spacesuit docking ports for every EVA where possible.

While the lunar soil contains a large amount of oxygen which could be extracted by heating the lunar dust, the mission of Phoenix Program on the surface of the Moon would take no more than a few days due to the extremely intense cosmic ray afflicting the surface of the Moon, and therefore, the astronauts could only rely on air supplies they brought to the Moon themselves.



134. The Orion spacecraft flying over the Moon and an earthrise during Artemis I (Artist's Concept) (Credit: NASA)

Once the exploration vehicle and the shelter base module are furnished, the astronauts could start working on their scientific tasks, which would primarily involve collecting samples from the surface of the Moon. The astronauts could roam the close proximity of the landers within a few kilometres thanks to the high-capacity batteries of the exploration vehicle, allowing them to collect samples from a dozen of different locations.

Since the mission of Phoenix Program on the surface of the Moon would take place near Artemis Base Camp, others would already have had wandered the surrounding areas several times by then, and for this reason, performing these scientific tasks would much rather be intended for a live testing of the equipment and tools for the mission on the surface of Mars instead of actual research works.



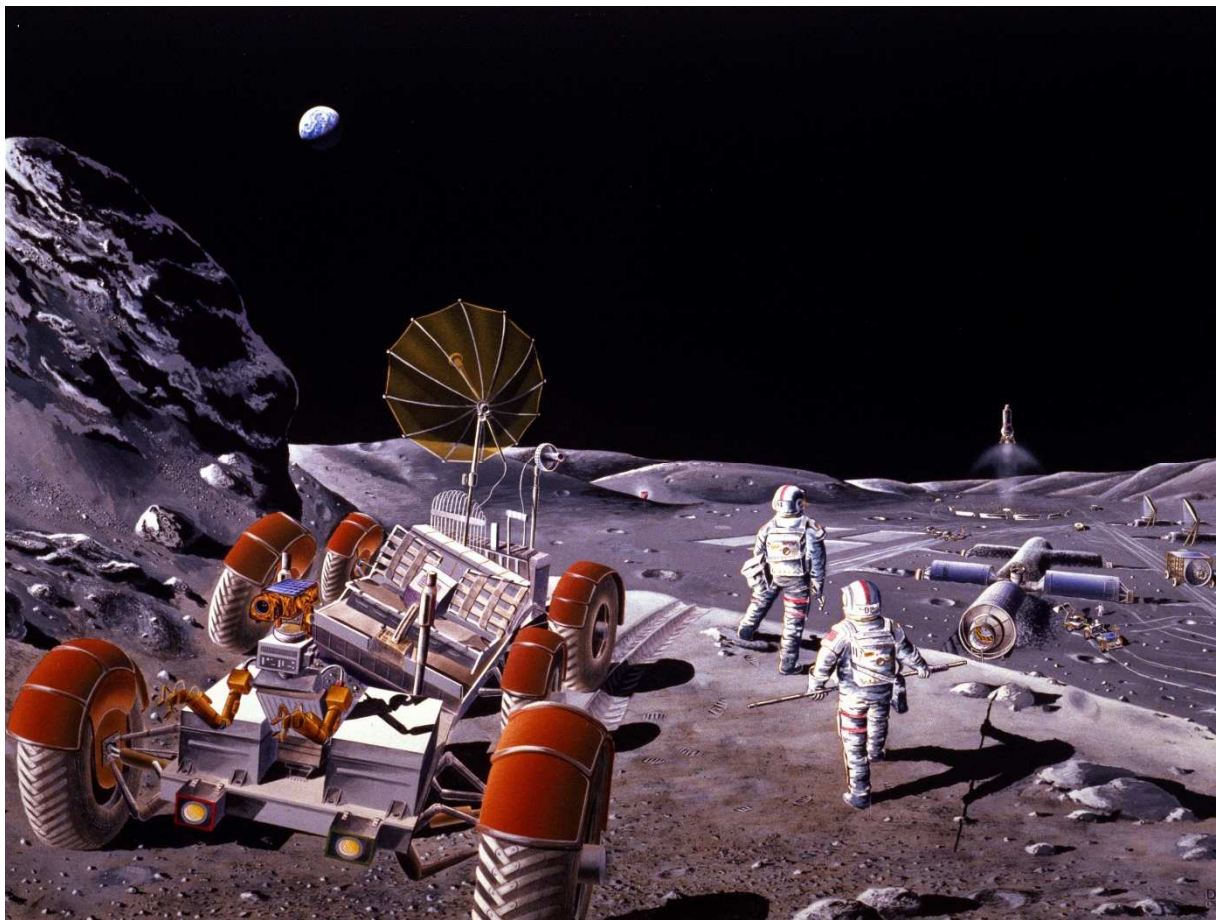
135. Apollo 17 astronaut Harrison H. Schmitt using a scoop to retrieve lunar samples (Credit: NASA)

Before taking off from the surface of the Moon, the astronauts would disconnect the landers – previously network-connected via their resource-distribution connectors through flexible charging cables –, and then would remotely drive the Mars shuttle and the two propellant shuttles – connected to the fixing points of the Mars shuttle – directly to one of the airlocks of the wind tunnel of the exploration vehicle.

Since the other landers, unlike the Mars shuttle, would have the shape of an inverted cone, the opening on the side of the crew module of the Mars shuttle could approach the airlock of the selected exploration vehicle within a few centimetres, and since the height of the landers could be

adjusted accurately with the ATHLETE robotic legs, the astronauts, after completely dedusting their xEMU spacesuits, could move from the airlock of the exploration vehicle directly to the crew module of the Mars shuttle without touching the lunar soil and without getting hazardous lunar dust on their spacesuits – which they could not get rid of once they are in the Mars shuttle.

In order to avoid getting lunar dust on the solar panels of the shelter base module and of Artemis Base Camp from igniting the rocket engine when taking off from the surface of the Moon, the astronauts would first drive the Mars shuttle and the two connected propellant shuttles several kilometres away using the fuel cells thereof. When taking off, the main rocket engines of all three landers would be used and would be controlled by the astronauts directly from the crew module of the Mars shuttle.



136. Moon colony with rover (Artist's Concept) (Credit: Dennis Davidson)

Upon reaching the gravity ring on geostationary orbit above Artemis Base Camp, the Mars shuttle and the two propellant shuttles would remain connected when docking at the docking port of the life-supporting space station module of the gravity ring, and then the astronauts coming from the surface of the Moon would go through the docking port towards the space habitat module of the gravity ring. After taking a rest, the astronauts would take a spacewalk to reconnect the propellant shuttles with the Mars shuttle through their resource-distribution connectors on their outer casing, allowing both the Mars shuttle and the two propellant shuttles to be refuelled completely with liquid hydrogen and liquid oxygen through the docking port of the life-supporting space station module.

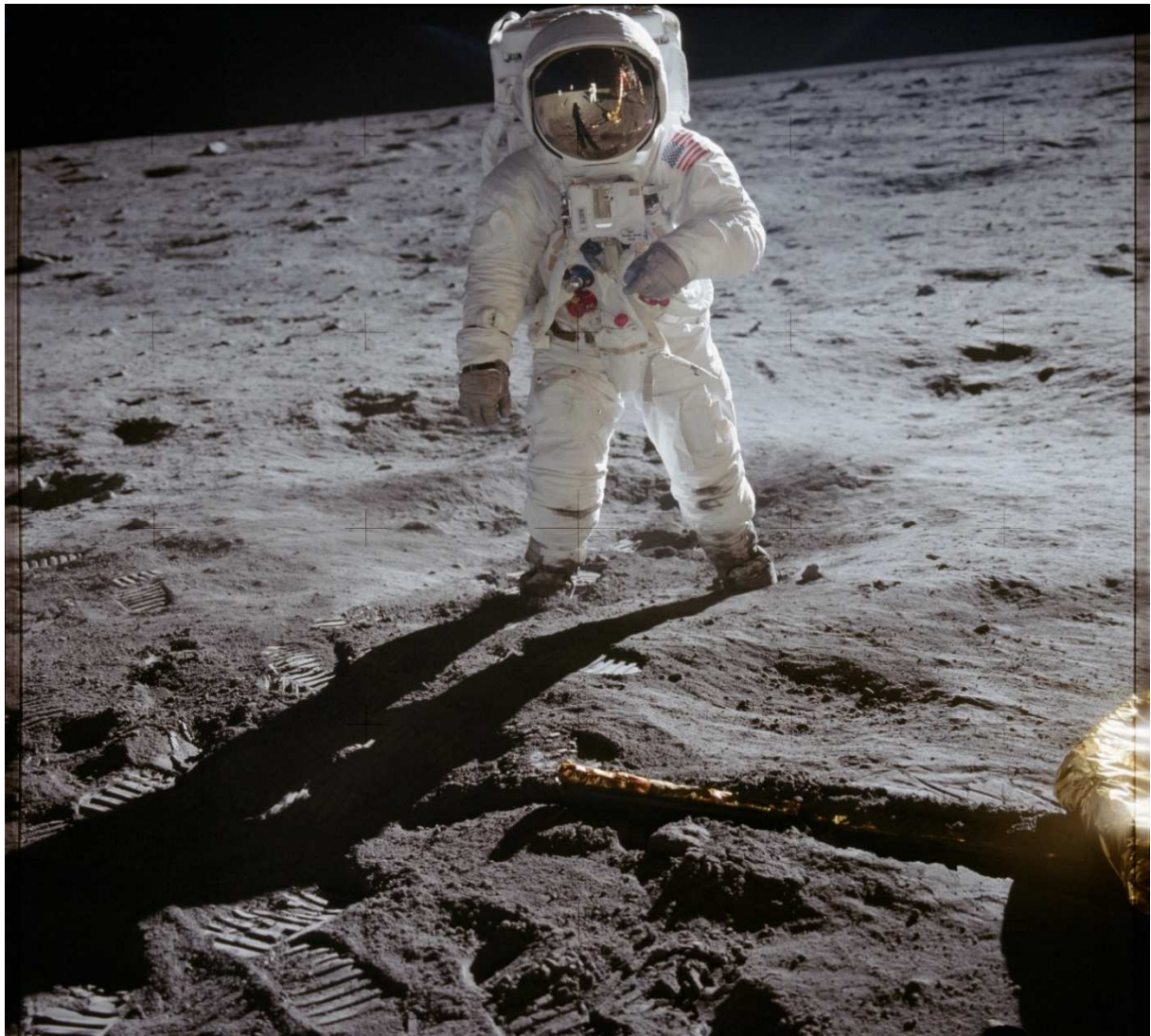


137. Apollo 17 astronaut Harrison H. Schmitt at a huge boulder near the Valley of Taurus-Littrow (Credit: NASA)

After this, the Mars shuttle and the two propellant shuttles would be controlled remotely to land on the surface of the Moon again, but this time, the shuttles would not land separately, but would remain connected to one another through their fixing points. After landing, the shuttles would use their ATHLETE robotic legs – powered by their own fuel cells – to move to another location on the surface of the Moon which is still near Artemis Base Camp, but is also shaded constantly, e.g. by a crater wall, allowing the propellant shuttles to keep their LOX/LH2 rocket fuel – remaining after the landing – in liquid state permanently without using their cooling systems.

The radioisotope thermoelectric generator in the Mars shuttle could provide sufficient energy for the energy efficient, yet permanent operation of the communications- and control systems of the Mars shuttle, and could also produce sufficient heat for maintaining the optimal temperature of the sensitive electric equipment consistently; this would allow the three interconnected landers to be on stand-by constantly while parked in the shadow, and to be used as an emergency reserve for any subsequent missions on the surface of the Moon.

Once the mission on the surface of the Moon is completed, the gravity ring would return from lunar orbit to low Earth orbit with the astronauts to prepare for the Mars mission.



138. Apollo 11 astronaut Buzz Aldrin walking on lunar surface (Credit: NASA)

Chapter 5: Let's Go to Mars!

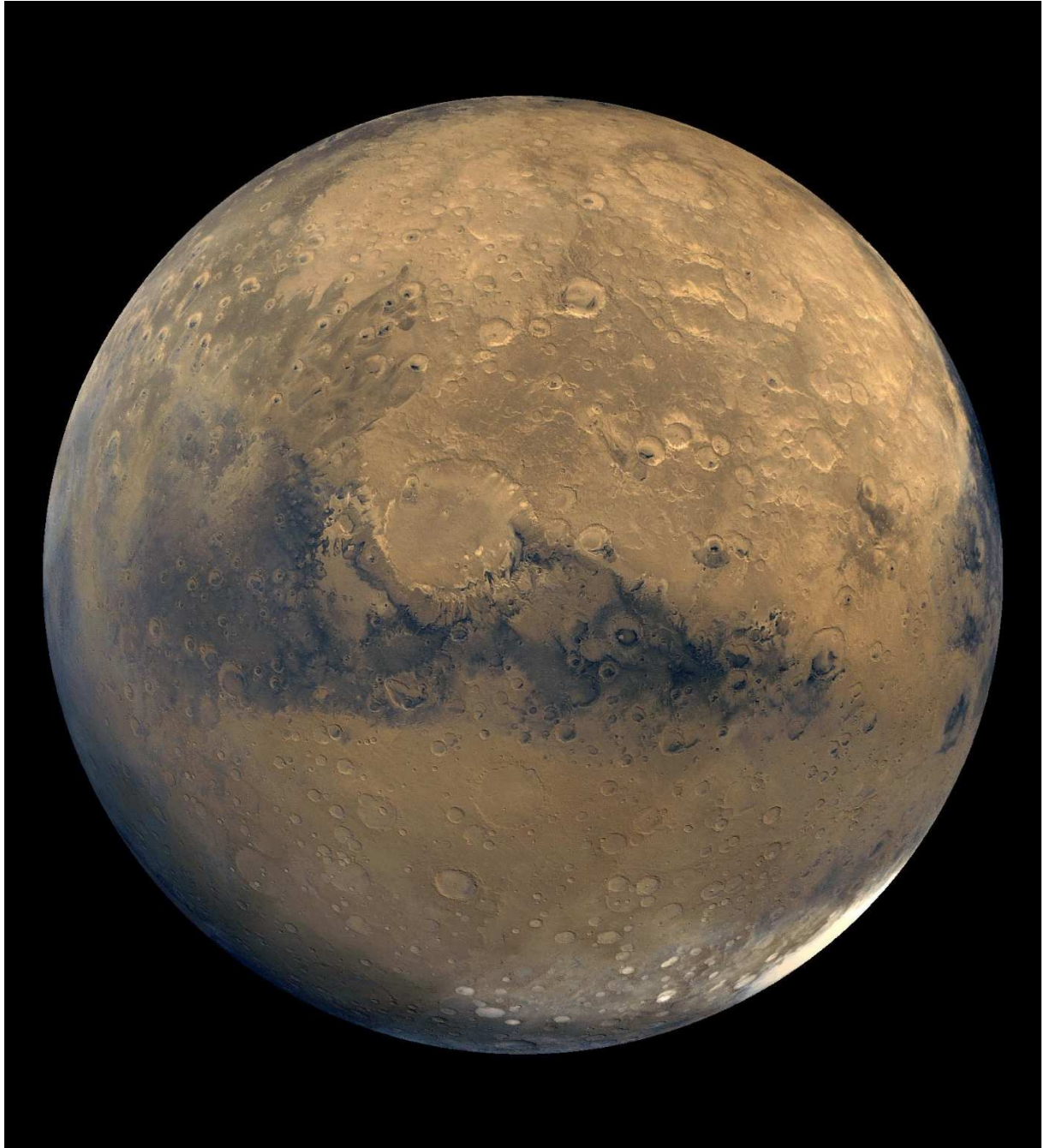
Since the Mars mission of Phoenix Program would launch from low Earth orbit where the magnetic field of the Earth provides a relative protection against cosmic ray both for the astronauts – taking countless spacewalks throughout the preparations for the Mars mission from constructing the gravity ring to pumping several hundred tonnes of LOX/LH2 rocket fuel from the consistently arriving propellant carrier spaceplanes – and for the gravity ring and its connected space station modules – which would eventually become radioactive due to the constant cosmic ray in deep space –, it would be no problem at all if the departure for Mars would occur several years after the lunar test programme.

As the gravity ring would practically serve as a new International Space Station throughout the preparations on low Earth orbit, the fully exploitable abilities of the gravity ring – by utilising the former space station modules of the International Space Station to provide a platform for different subjects from crop production to material researches to scientific research programmes of all kinds, and certainly to significantly growing space tourism – would allow a much more flexible choice of optimal launch time for the Mars mission.



139. Mountainous Crater Rim on Mars (Artist's Concept) (Credit: NASA)

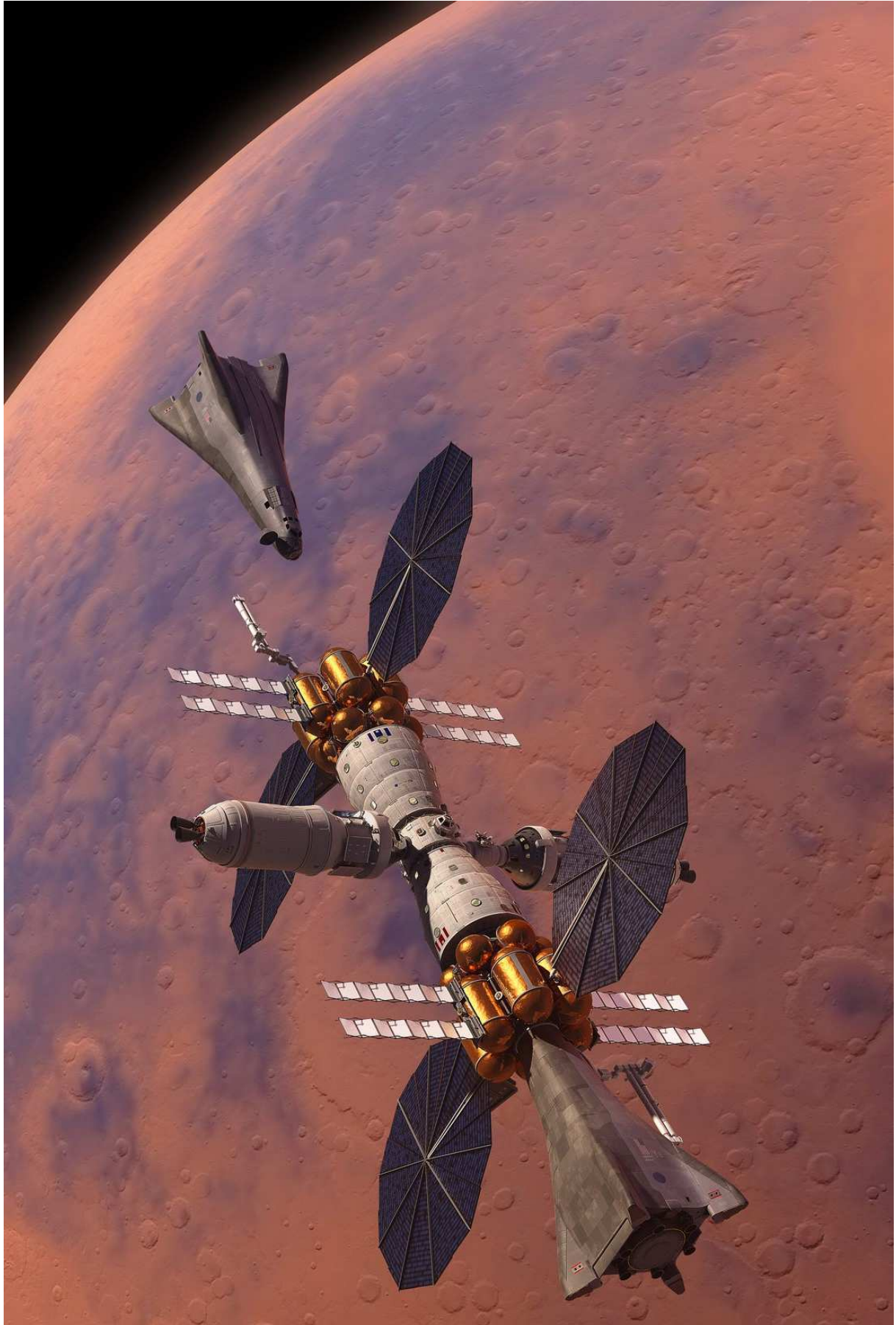
This would allow selecting the launch time based on not only the optimal distance between the Earth and Mars, but also on the maximum of solar activity, where the solar activity diverts some of the high-energy particles coming from distance galaxies, thus mitigating the radiation exposure of the astronauts. Consequently – despite the fact that this would result in the journey taking almost nine months –, the astronauts could take the most energy efficient Hohmann transfer orbit towards Mars, while the abundance of LOX/LH2 rocket fuel could be saved for emergencies and for the return to the Earth.



140. The Red Planet (Credit: NASA)

While the speed of revolution of the gravity ring would be adjusted to simulate Martian gravity throughout the lunar test programme, several years may be spent with preparations for the Mars mission after returning to low Earth orbit, which would allow NASA to repeat the twin experiment conducted previously with the Kelly brothers, however, the research programme would now aim to examine how the human body adapts to Martian gravity, providing key medical data way before the six astronauts selected for the Mars mission were to leave for Mars.

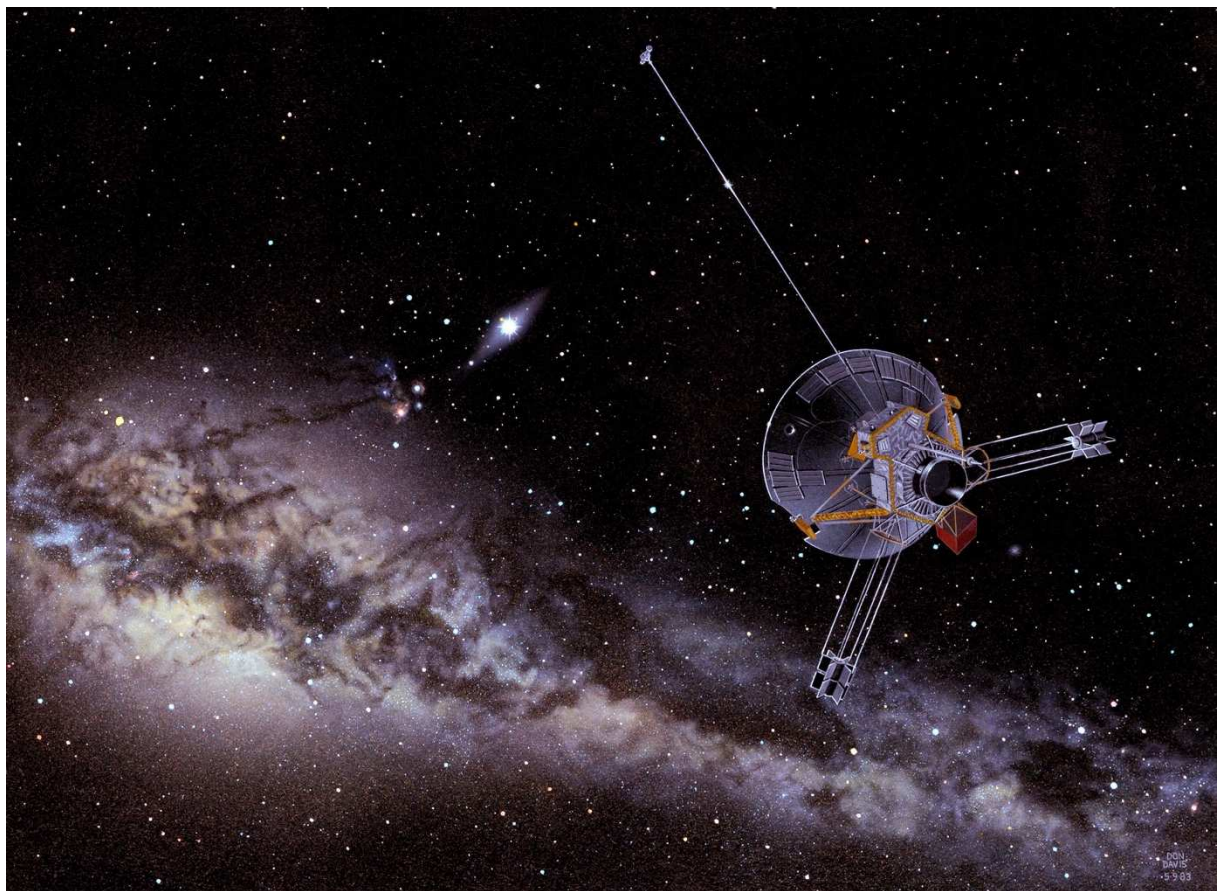
Once all preparations for the Mars mission are concluded and all the necessary space station modules, spacecrafts, landers, devices and equipment are installed in or connected to the gravity ring, the astronauts of the Mars mission would depart for Mars with the gravity ring at the optimal launch time, using the NTP engine module for course corrections.



141. Lockheed Martin Mars Base Camp (Artist's Concept) (Credit: Lockheed Martin)

As only the space habitat module of the gravity ring would be protected sufficiently against micrometeorites, cosmic ray and solar flares for the astronauts, the gravity ring, despite its large size, would provide an extremely limited habitat for the astronauts throughout the Mars mission, which may take up to two years. The astronauts would consequently have no opportunity to spend the tedious months of their journey in deep space with different scientific researches, because their tight habitat would not allow to do anything else beyond recreation and regular exercises.

Another issue beyond condemnation to idleness is that the nine months from the completion of the preparations above the Earth until the actual initiation of the mission on the surface of Mars is too long of a period to keep the mission tasks practiced endlessly during the preparations on the Earth ingrained. These nine months may very well give rise to forgetting a lot and thus making many mistakes, moreover, ground mission control centre will also have much more restricted support opportunities than in the case of Apollo 13 due to several minutes of communication delay.



142. Pioneer 10 leaving the planets behind (Artist's Concept) (Credit: Don Davis)

For this reason, Phoenix Program would also address developing a simulator program which would allow the astronauts to practice each and every tiny detail of the entire Mars mission constantly using a computer, from handling the technical service spacecraft and the landers, to all kinds of emergency scenarios, to constructing the Mars base. This simulator program would allow the astronauts to keep their knowledge fresh consistently, so that once they reach Mars and actually need to utilise their knowledge, they could perform their extremely complicated tasks without any mistake and hesitation, and would follow the relevant emergency protocol in case of any emergency.

5.1 Non-Mission-Critical Reserves

Since only six astronauts would go to Mars within Phoenix Program, which is a small number of crew members compared to the available space station modules, spacecrafts, devices and different equipment of the Mars mission as well as the reserves thereof, the everyday consumption of the astronauts – from oxygen breathed in to foodstuff consumed – could be provided without any difficulties, as six astronauts couldn't consume several tens of tonnes of foodstuff throughout a Mars mission, which may take up to two years, even if they eat an abundant and balanced diet.

The problem is rather the fact that the longer a deep space mission, the more difficult it is to provide foodstuff which actually gives a fresh impression and a natural taste, while being rich in both calories and vitamins. The quality of foodstuff is indeed very important to maintain the health and moral of the astronauts at a high level, particularly in the case of a long-term and dangerous Mars mission, however, the space habitat module of the gravity ring, which provides protection against micrometeorites and cosmic ray, would not be suitable for crop production at all due to its limited space.



143. Ingenuity helicopter on Mars (Credit: NASA)

With this, the astronauts may have a relatively delicious and nutritious diet through the journey of nine months from the Earth to Mars, however, they could only consume instant food on the surface of Mars and through the entire return journey, which can be stored nearly for an unlimited period of time, but is filled with preservatives.

A key concern of conquering Mars is crop production on Mars. Currently, the toxic Martian soil, contaminated with perchlorates, does not seem suitable for crop production at all, however, the astronauts landing on the surface of Mars could devote their weeks or months spent on Mars to grow fresh vegetables in the aeroponic base module, without using Martian soil.



144. Rocks on Mars (Credit: NASA)



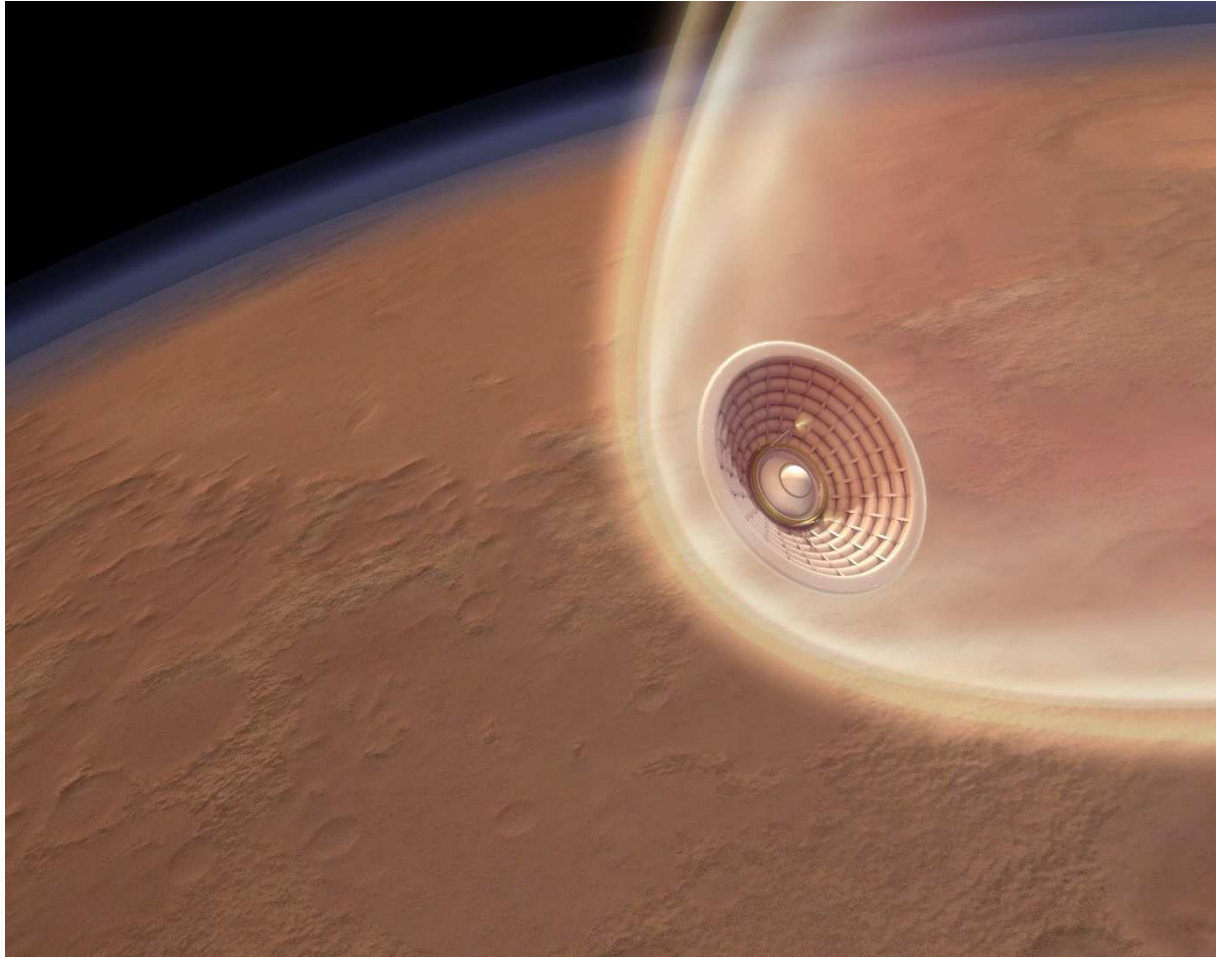
145. Martian food production (Artist's Concept) (Credit: NASA)

A great advantage of aeroponics – feeding the roots of plants with nutrients in the form of spray – is that plants can be grown on a shelving of a simple structure, allowing the astronauts to exploit almost every cubic centimetre of the aeroponic base module to grow vegetables, and the astronauts could even take the dried vegetables with them to the gravity ring when launching from Mars.

At the same time, however, crop production for purposes beyond scientific researches is extremely resource-consuming, and the payload capacity of the Mars shuttles would primarily be reserved for rock samples when launching from Mars, and thus, as growing vegetables on Mars would not be crucial for the success of the Mars mission, it would not be of priority in Phoenix Program either.

In the same vein, there are many other materials and items beyond the nutrients for growing vegetables which would be sufficient in a minimum amount for the success of the mission on the surface of Mars, but at the same time, a large amount of these could greatly facilitate the everyday lives of the astronauts, or could simply boost their well-being and moral.

For this reason, simultaneously with launching the gravity ring to Mars, one or several other custom-designed landers would also be launched to Mars filled with non-mission-critical reserves. These customized landers, taken directly to Mars orbit by SpaceX Falcon Heavy launch vehicles, would not be provided with landing gear or rocket engines required for braking to land on the surface of Mars. Instead, these customized landers would only be provided with supersonic parachutes and NASA HIAD heat shields inflatable to a diameter multiple of their own size, allowing only aerodynamic deceleration before reaching the surface of Mars, where they would land at a speed of nearly 200 km/h.

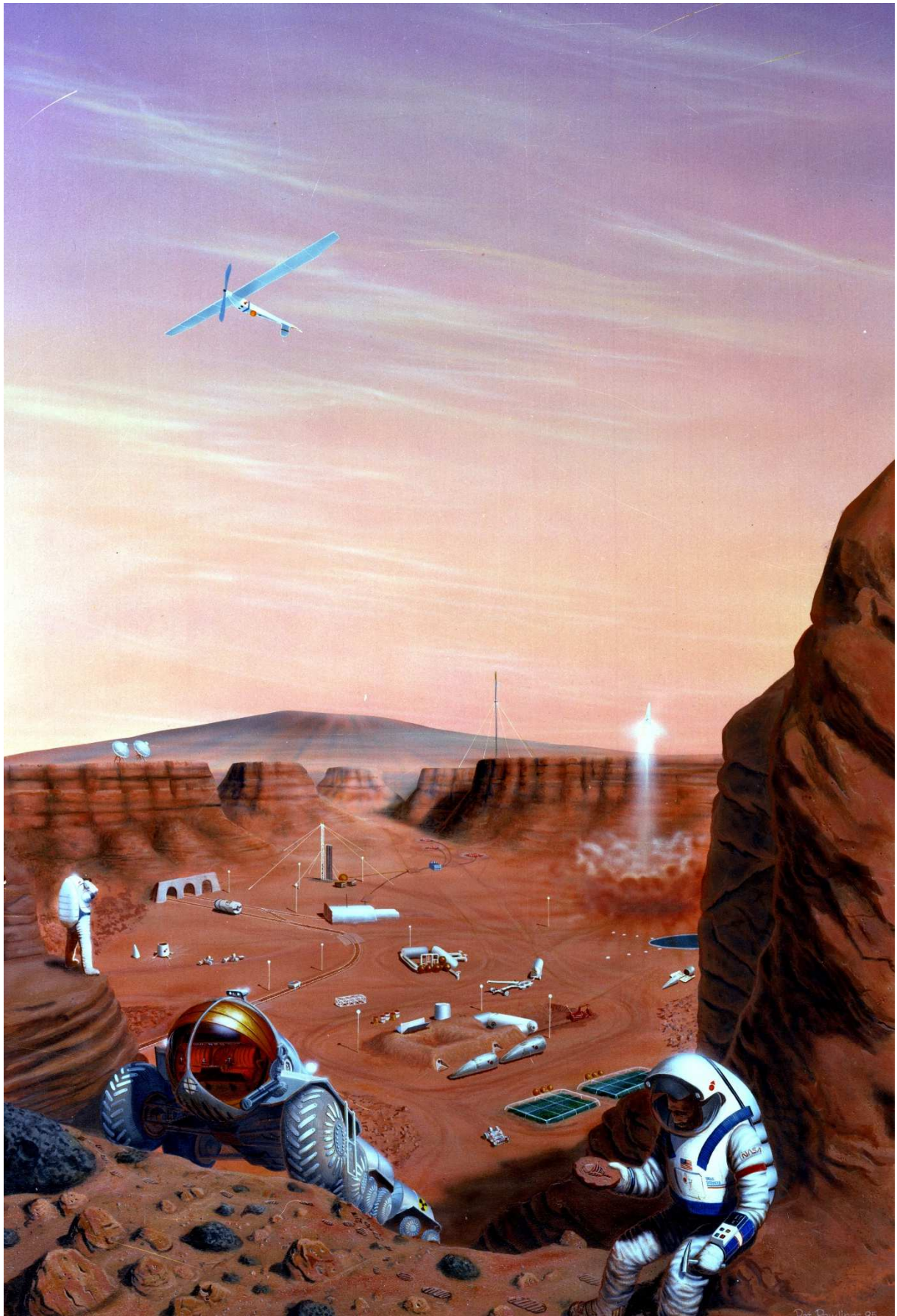


146. Hypersonic Inflatable Aerodynamic Decelerator (HIAD) (Artist's Concept) (Credit: NASA)

Since these customized landers would hit the surface of Mars near the planned location of the Mars base at a high speed without rocket braking, these landers could only transport reserves which are able to endure the forces of such impacts. In order to ensure that only the landers are destroyed upon the impacts and that the transported materials and items remain intact, the different kinds of reserves transported in these landers would be stored in hollow metal spheres with a half-meter diameter. These spherical tanks would be made of an aluminium alloy with a low melting temperature, and would be strong enough to only roll around when the landers hit the surface, allowing the astronauts to collect those with autonomous robots once the Mars base is established.

These spherical aluminium tanks would represent such an extra weight in the customized landers that landing could also be executed with rocket braking, however, these metal spheres would not only ensure the protection of non-mission-critical reserves against high-speed impact, but the metal spheres themselves would also be considered as one of these materials.

The workshop base module would be equipped with a furnace designed specifically for the size of these metal spheres, and this furnace could be used to melt these metal spheres to create new structural elements. The potential to create aluminium structural elements of all kinds is extremely important, as the astronauts might need an extra heavy-duty ladder step or may have to repair a broken ATHLETE robotic leg using a spare part, or may even want to establish a permanent Mars base on another Mars mission with 3D printed buildings.



147. Living and working on Mars (Artist's Concept) (Credit: Pat Rawlings)

5.2 The Robotic Dog: an Astronaut's Best Friend

A completely flat area would be selected on the surface of Mars as the landing zone for the Mars landers of Phoenix Program, allowing the landers – with the help of their fuel cells powered by gaseous hydrogen and oxygen as well as their ATHLETE robotic legs with wheels at the end – to easily move from the landing zone to the nearby area selected for establishing the Mars base.

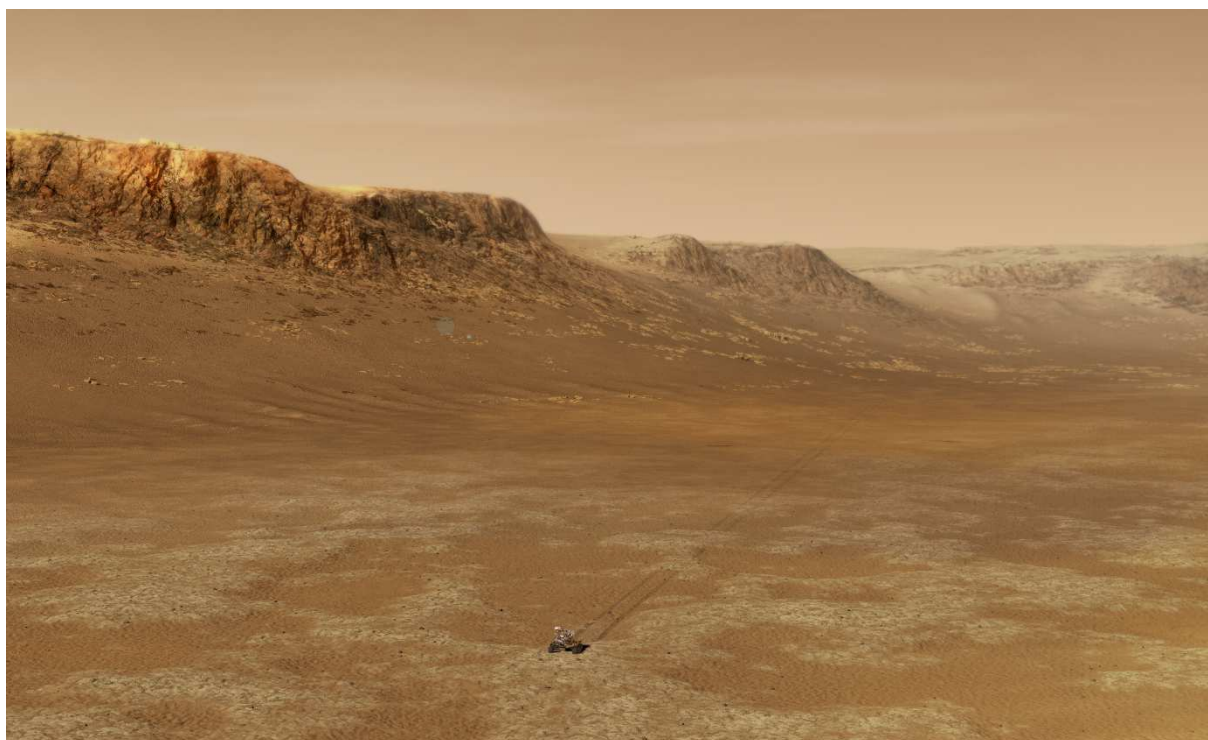
In the same vein, astronauts in xEMU spacesuits could also work, establish the Mars base and collect rock samples easier on a flat surface, however, in the absence of a thick atmosphere absorbing radiation and a magnetic field redirecting high-energy particles, the astronauts will have to minimise works performed in spacesuits due to the dangerously high levels of cosmic ray afflicting the surface of Mars, and for this reason, the mission on the surface of Mars would also have robots to replace EVA as much as possible.



148. Boston Dynamics BigDog (Credit: Boston Dynamics)

A humanoid robot could most easily perform the same tasks as an astronaut, however, in order to have as widely usable robots as possible on the surface of Mars, Phoenix Program would use robotic dogs based on BigDog by Boston Dynamics.

Each of these large robotic dogs would also be equipped with two separate robotic arms on the back. The gripper of the anterior universal robotic arm – which would be used for performing different tasks – could be replaced easily, so that the robotic dogs could facilitate or completely take over tasks from the astronauts, from drilling the soil in a depth of a few tens of centimetres to grasping objects of all kinds. The robotic dogs themselves could also replace the gripper of this anterior universal robotic arm, so that the astronauts wouldn't have to engage in EVAs when the robotic dogs are performing tasks in an autonomous or remotely controlled manner to replace the grippers between each phase of work.



149. Exploring the majestic Jezero crater (Artist's Concept) (Credit: NASA)

The other, posterior robotic arm of the robotic dogs to be developed within the framework of Phoenix Program would have a gripper to be connected to the resource-distribution connectors on the casing of any Mars lander, making the robotic dogs capable of connecting autonomously to any lander with a free resource-distribution connector, which, beyond allowing the robotic dogs to establish a direct energy- and data link, would also allow to refuel the robotic dogs with liquid hydrogen and liquid oxygen.

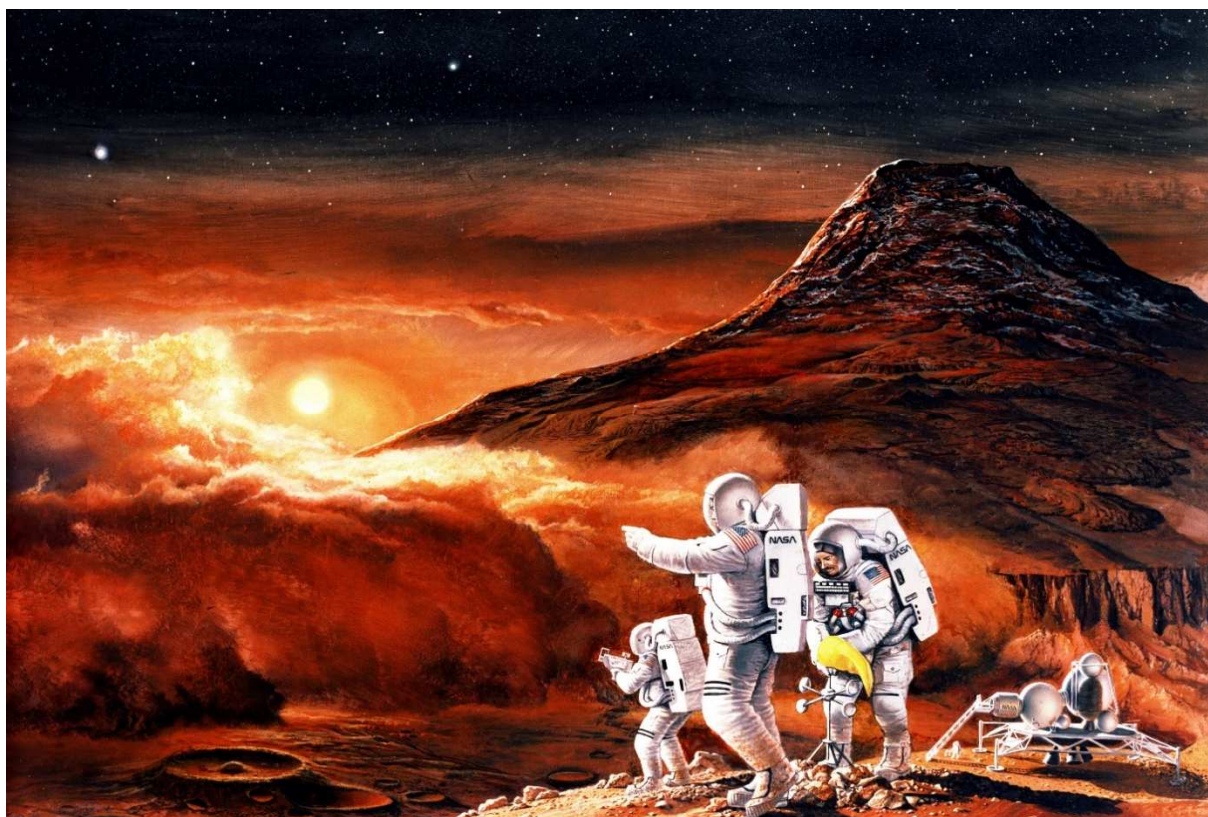
The robotic dogs' cryogenic tanks storing liquid hydrogen and liquid oxygen would have the same volume, because the so-stored hydrogen and oxygen would not only be intended to power the fuel cells of the robotic dogs, thus ensuring a long service life and a significant effective range for the robotic dogs, but would also provide the astronaut currently connected to the given robotic dog with energy and oxygen.



150. Collecting samples from the eastern cliff at the base of Olympus Mons (Artist's Concept) (Credit: Pat Rawlings)

The reason for this is the introduction of a new EVA protocol for Phoenix Program, within the framework of which, each astronaut would be connected to a robotic dog on a mandatory basis when performing tasks on the surface of Mars in a spacesuit, regardless of the duration of each EVA. This connection would provide the astronauts' energy- and oxygen supply, while the astronauts would use the energy- and oxygen reserves of their own spacesuits in emergency cases only.

The required flexible supply pipe – incorporating the oxygen hose, the energy cable and the data cable – would be an integrated component of the xEMU spacesuits of the astronauts. This xEMU supply pipe – the unwound length of which would be ten metres approximately – would have a gripper at the end, which could be connected to the resource-distribution connectors by virtue of its compatibility, allowing the astronauts to connect not only to any robotic dog, but to the landers as well.



151. Dust storm on Mars (Artist's Concept) (Credit: Ren Wicks)

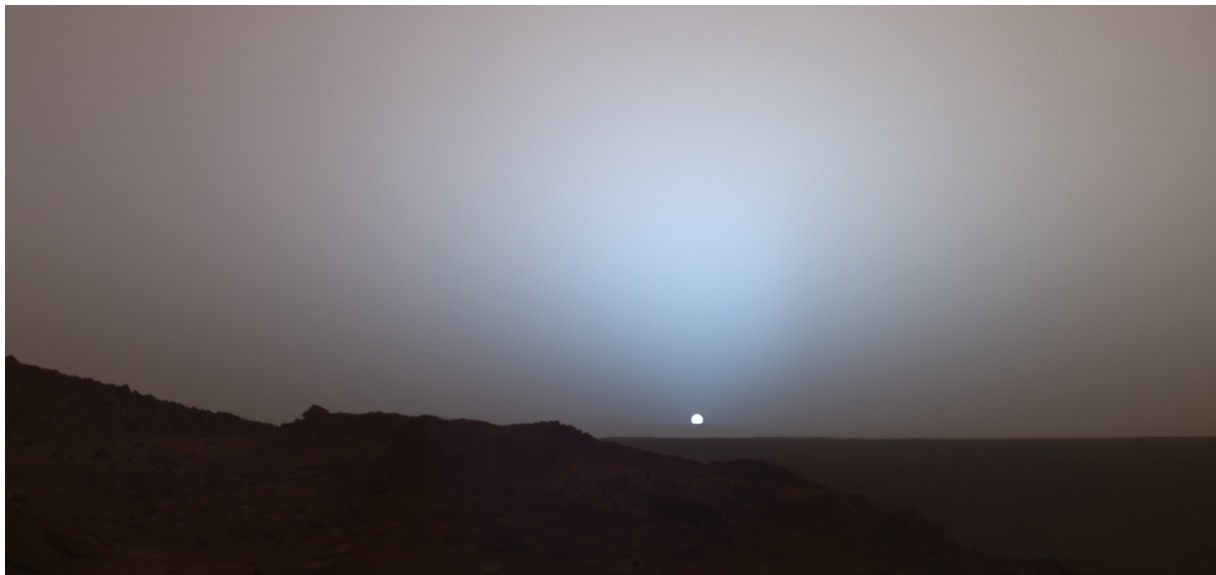
The latter would be of particular importance when the astronauts were to drive several kilometres away from the Mars base using the Mars exploration vehicle to collect rock samples, because in such cases, the astronauts could plug their xEMU supply pipes in the two resource-distribution connectors of the Mars exploration vehicle if they do not intend to move further from the lander than ten metres, thus making their work on the surface of Mars safer without having to avail themselves of the robotic dogs.

The grippers at the end of the xEMU supply pipes could also be connected to one another, so that in case of an emergency, an astronaut could connect its xEMU supply pipe directly to its partner's spacesuit, thus sharing their spacesuits' energy- and oxygen reserves, and, among others, their carbon dioxide absorption capacities as well.

Should an astronaut need to move away from the landers, the robotic dog – based on the technology of Boston Dynamics –, by virtue of its advanced artificial intelligence, could follow the astronaut walking on the surface of Mars autonomously, without remote control, and maintain a consistently ideal tension of the flexible xEMU supply pipe connecting the astronaut to the robotic dog.

Since the robotic dogs would use two different robotic arms for performing tasks and for connecting to the astronauts, the robotic dogs could not only accompany the astronauts, but could also work together with them – from lifting objects to welding by flame to many other different tasks, where the robotic dogs would always be positioned so that the xEMU supply pipes would be the least disturbing when working together.

Constant connection to a robotic dog would not only reduce risks of the given astronaut concerning life support, but would also open up new possibilities, as the data link between a robotic dog and an astronaut would allow the astronaut to access every device of the robotic dog, from its broad waveband infrared camera to its LIDAR and to its radio of high data rate.



152. Sunset at Mars' Gusev crater (Credit: NASA)

The robotic dogs would have both their anterior robotic arms – intended for performing tasks – and their posterior robotic arms – providing the connection to the xEMU supply pipe – equipped with an extremely high-intensity lamp, which, on account of their omni-directionability, would allow the robotic dogs to perfectly illuminate the current worksite or the area in front of a walking astronaut, allowing astronauts connected to robotic dogs would be able to work safely at night or in conditions of limited visibility.

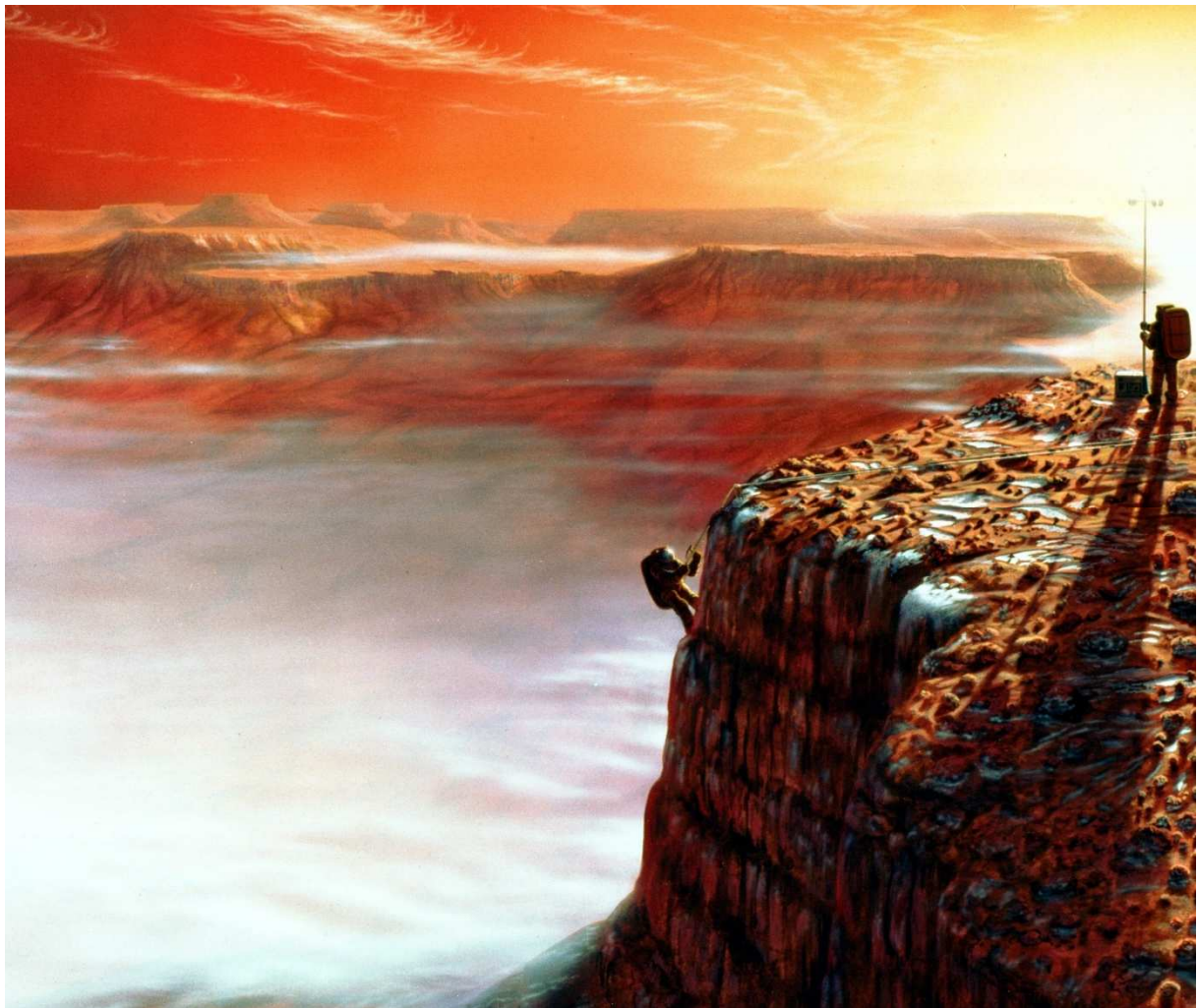
The anterior robotic arms of the robotic dogs intended for performing tasks would be equipped with a nozzle to blow compressed Martian air at a high pressure – using the compressor installed in the robotic dogs –, allowing the astronauts to get rid of most of the dust covering them on the surface of Mars, before returning to the exploration vehicle, thus reducing time spent in the wind tunnel on dedusting, and also increasing the lifespan of the dust filters installed in the return-stream air-pipes of the wind tunnel.



153. Seeking evidence for life (Artist's Concept) (Credit: Pat Rawlings)

Since xEMU spacesuits are practically miniature spacecrafts weighing more than a hundred kilograms, wearing these requires extreme physical effort despite the low Martian gravity, even if a load-bearing exoskeleton were also developed for the Martian version of the xEMU spacesuits within the framework of Phoenix Program, and consequently, it would be nearly impossible for an astronaut to carry another astronaut and its spacesuit in case the latter were to be rendered incapacitated during an EVA due to, for example, loss of consciousness.

For this reason, xEMU spacesuits would also be equipped with a dozen of special mounting connectors distributed evenly on the outer surface. These mounting connectors would work similarly to the latches and buckles of seatbelts, however, these mounting connectors could be released not only by pushing the buttons on them, but through remote control as well. The robotic dogs would be able to connect to these mounting connectors using both of their robotic arms, allowing a robotic dog to drag, and two robotic dogs to carry any helpless astronaut.



154. Humans explore Martian canyons at dawn (Artist's Concept) (Credit: NASA)

Since the fuel cells of the robotic dogs would consume hydrogen and oxygen in gaseous state for producing energy, and the astronauts would also be supplied with gaseous oxygen through the xEMU supply pipes, the liquid hydrogen and liquid oxygen tanks in the robotic dogs would not have perfect thermal insulation, and their cryogenic tanks would not be equipped with cooling systems either, thus reducing the weight of the robotic dogs.

While the primary energy source of the robotic dogs would be the fuel cells using gaseous hydrogen and oxygen, the robotic dogs would also be equipped with a battery providing at least two hours of operation. These batteries would not only be for emergency cases, but would also allow the robotic dogs to perform tasks constantly while relying solely on the batteries in cases where the robotic dogs do not have to accompany the astronauts or move far away from the landers.



155. Santa Cruz hill on Mars (Credit: NASA)

Since a total of four astronauts would land on the surface of Mars in two Mars shuttles within the framework of Phoenix Program, four robotic dogs would be among the equipment of the Mars base. The robotic dogs would be settled in the nuclear supply module when landing on the surface of Mars, allowing them to leave the lander autonomously after landing. The replaceable grippers of the robotic dogs intended for performing different tasks would also be settled in the nuclear supply module, and would also be situated so that the robotic dogs could access those without any help from the astronauts.

The nuclear supply module, unlike the other Mars landers, would be provided with four – instead of two – resource-distribution connectors on the casing, so that the Mars base would always have enough free resource-distribution connectors to which the robotic dogs could connect for recharging. Through these connectors, the robotic dogs could not only charge themselves, but could also pump the water produced by the operation of their fuel cells, and then the propellant shuttles could use their rocket fuel recirculation systems to produce new LOX/LH2 rocket fuel from this water.

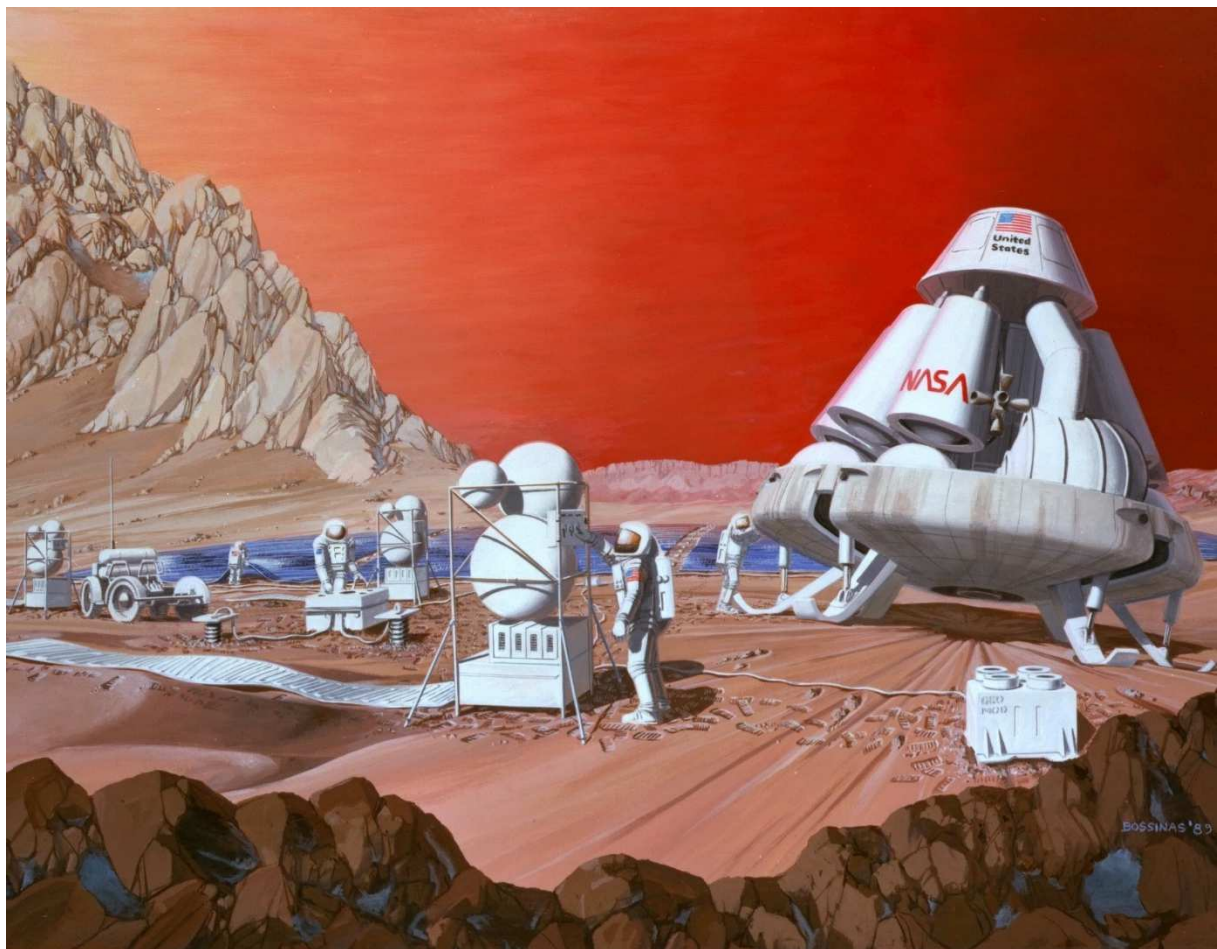
Since all the landers – including the nuclear supply module providing the Mars base with constant energy, but excluding the two Mars shuttles and the two propellant shuttles per Mars shuttle aiding each Mars shuttle in the take-off – would remain on the surface of Mars once the mission has been completed in order to prepare for the next manned Mars mission, the entire Mars base could use its ATHLETE robotic legs to move several thousand kilometres to another area, which might be less ideal for landing the new landers, but could be much more interesting scientifically.

In case the Mars base is moved, the robotic dogs could return to their original storage spaces in the nuclear supply module, so that the robotic dogs wouldn't have to take this very slow trip of up to several years on foot, thus reducing the risk of malfunction resulting from excessive wear.

In case the new location designated for the Mars base would be too rocky for the safe landing of the landers of the next Mars mission, the Mars base would firstly not move to its permanent location, but to the designated landing zone where the robotic dogs, relying solely on their own batteries operating for two hours, could completely clear the bigger rocks from an area of several square kilometres before the astronauts of the next Mars mission were to arrive. In this case, the Mars base would move to its designated location only after the landing zone is prepared completely.

5.3 The Mars Base

In preparation of landing on the surface of Mars, the astronauts aboard the gravity ring on geostationary orbit above the planned location of the Mars base would firstly stop the rotation of the gravity ring, so that the change of weight distribution of the gravity ring caused by detaching the landers would not destabilise the gravity ring, and then the astronauts would detach the eight propellant shuttles – already filled completely with LOX/LH2 rocket fuel – from the gravity ring one by one, which would then land in the designated landing zone one after another.



156. Human mission on Mars (Artist's Concept) (Credit: Les Bossinas)

TECHNICIANS WANTED



157. *Technicians Wanted* - NASA recruitment poster (Artist's Concept) (Credit: NASA)

Since the astronauts would be on geostationary orbit aboard the gravity ring, remotely controlled landing would be possible – unlike Mars missions supervised from the Earth –, in which case, landing would be conducted by the landers' own on-board flight control computers, but the astronauts on the gravity ring could still interfere with the flight control at any time in case issues were to occur in any autonomous flight. For this purpose, one of the two astronauts who are not involved in the mission on the surface of Mars would be trained specifically for the remotely controlled landing of the landers.

Once all of the eight propellant shuttles have landed in the designated landing zone on the surface of Mars, the astronauts would detach the base modules, the two Mars exploration vehicles and the nuclear supply module from the edge of the gravity ring, and then would take these to the life-supporting space station module of the gravity ring one by one, where the astronauts would use the robotic arm to hold them while being refuelled one after another with LOX/LH2 rocket fuel through their resource-distribution connectors, and then – similarly to the propellant shuttles – these landers would also land on the surface of Mars while controlled remotely.



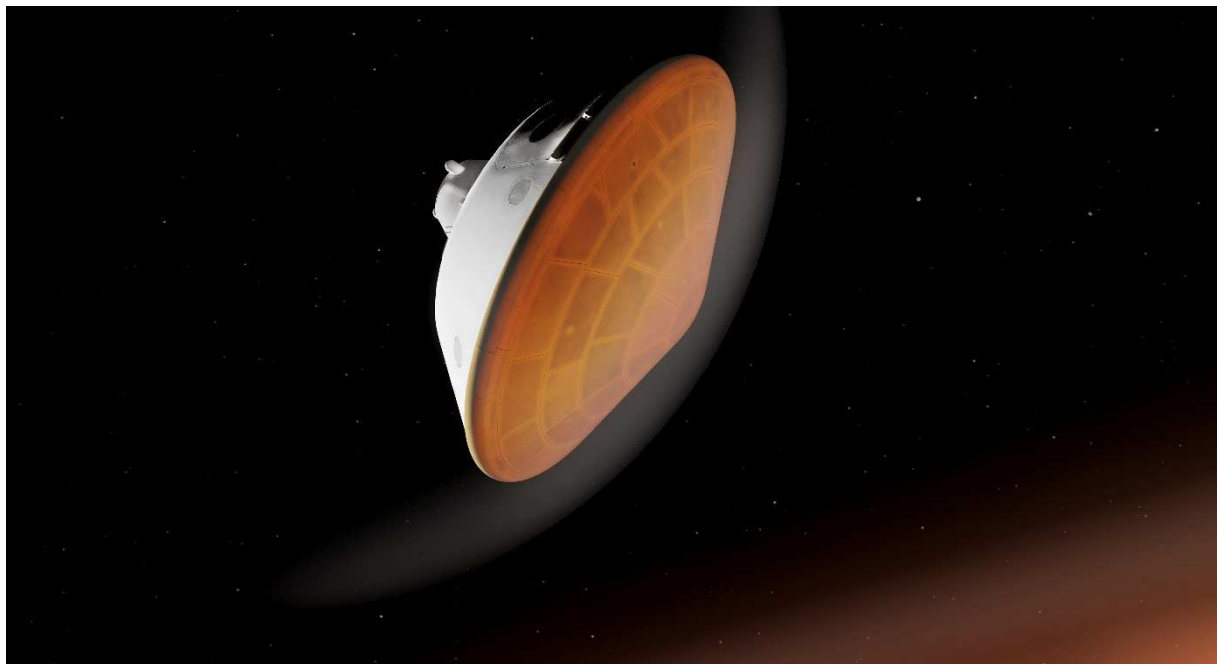
158. SpaceX Mars base (Artist's Concept) (Credit: SpaceX)

Once the landers required for establishing the Mars base have successfully reached the landing zone, each lander would move separately to the planned location of the Mars base through remote control and using their own ATHLETE robotic legs, so that the astronauts, prior to landing themselves, could investigate whether any malfunctions have occurred during the landings which may render gathering the landers impossible.

After this, the astronauts would prepare the two Mars shuttles for landing by docking them at the docking port of the life-supporting space station module of the gravity ring separately for refuelling with LOX/LH2 rocket fuel and for allowing the astronauts to embark them.

Since only two astronauts would land with one Mars shuttle, the mission on the surface of Mars could still proceed in case of any disaster. Once the first Mars shuttle has landed successfully, the other two astronauts would also set off with the next Mars shuttle, and the two astronauts who are not involved in the mission on the surface of Mars would stay on the gravity ring throughout the whole mission, accurately readjusting the centre of gravity and restarting the rotation of the gravity ring.

In case the asteroid mining experiments at the Moon were successful, and a suitable near-Mars asteroid could be set on Mars orbit before the arrival of the gravity ring, the two astronauts staying on the gravity ring could process this smaller water-rich asteroid throughout the months of the mission on the surface of Mars using the mining module.



159. Entering the Martian Atmosphere with the Perseverance rover (Artist's Concept) (Credit: NASA)

Once the astronauts have successfully landed on the surface of Mars and the two Mars shuttles have also moved to the other landers gathered at the planned location of the Mars base, the robotic dogs assisting the astronauts would awaken and leave their storages in the nuclear supply module, and then all of them would connect to a resource-distribution connector of any lander to refuel themselves completely with liquid hydrogen and liquid oxygen. Once the robotic dogs are completely ready for operation, the astronauts would put on their xEMU spacesuits in the crew modules of the Mars shuttles, and then would separately leave the Mars shuttles through the openings on the sides of the crew modules while monitored by the high-resolution cameras of the robotic dogs.

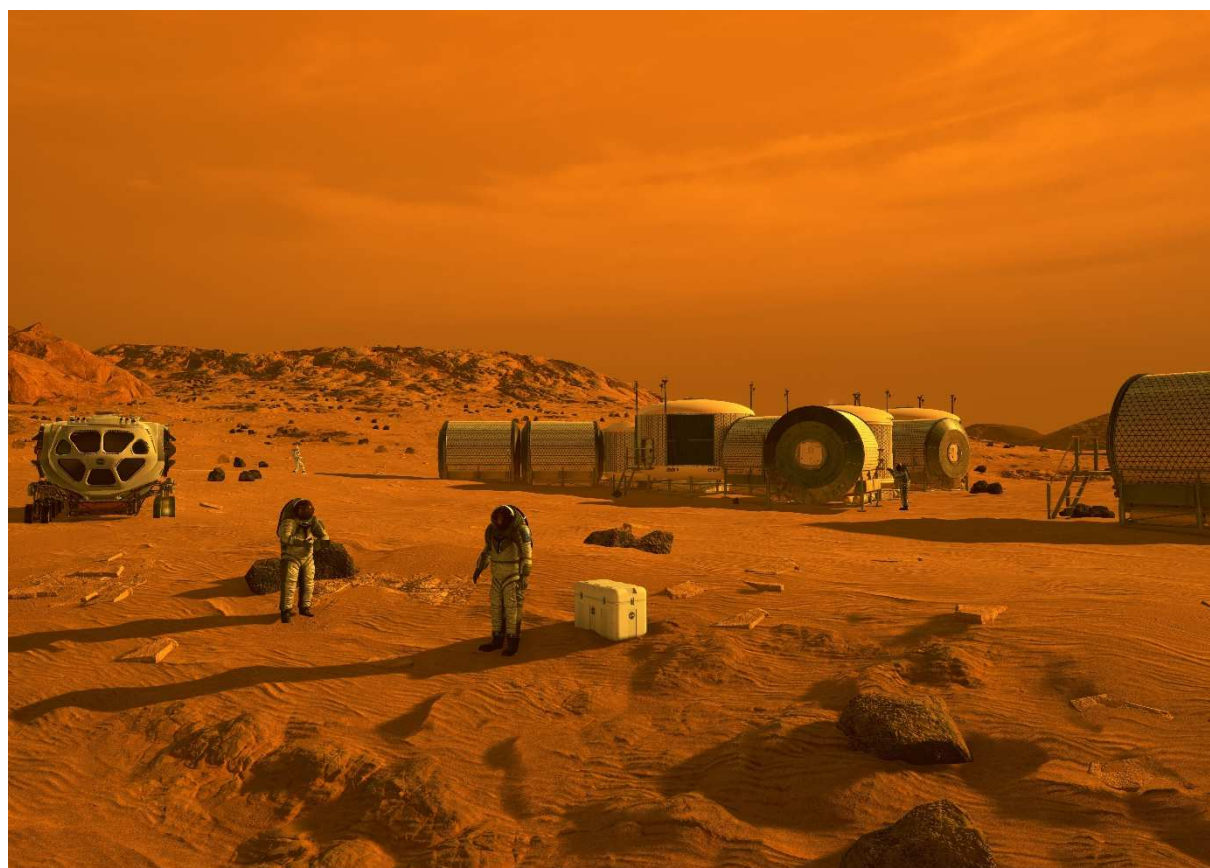
After the majestic moments, broadcast to every household on the Earth, the astronauts would immediately commence entering the two Mars exploration vehicles into operation with the method already verified in the lunar test programme, as at this time, the astronauts could only leave their spacesuits safely through the xEMU suitports of the exploration vehicles due to the lethality of Martian dust. As soon as the astronauts commence establishing the Mars base, the new EVA protocols would also enter into force, and each astronaut would have to connect to a completely recharged robotic dog through their xEMU supply pipes.



160. *Some User Assembly Required* - NASA recruitment poster (Artist's Concept) (Credit: NASA)

Once the donut-shaped secondary habitats of the exploration vehicles are inflated after releasing the fixing clamps on the side casing panels, and the astronauts can access the flexible charging cables in the tool- and equipment storage rooms of the exploration vehicles, the landers would be interconnected through their resource-distribution connectors. After this, the astronauts could safely enter the exploration vehicles through the xEMU suitports to take a brief rest.

The astronauts, after taking a rest, could engage in further EVAs to inflate the secondary habitats of the base modules by releasing the fixing clamps on the side casing panels, and then could level those accurately using their ATHLETE robotic legs to interconnect all the base modules through their airlocks one after another, thus establishing a united Mars base.



161. First Humans on Mars (Artist's Concept) (Credit: NASA)

Since the landers would remain interconnected through their resource-distribution connectors and the flexible charging cables, the astronauts, simultaneously with unpacking and checking the most important equipment in the secondary habitats of the landers, could start pumping the liquid hydrogen and liquid oxygen remaining after the landing into the propellant shuttles equipped with cooling systems, so that the astronauts could start using the exploration vehicles as wind tunnels and the liquid hydrogen tanks turned into base modules as primary habitats.

The astronauts would spend the following weeks with adapting and furnishing the Mars base to prepare for the scientific tasks and to leave Mars at any time in case of any emergency. While the base modules used for the mission on the surface of Mars would have the same size and structure, the internal structure of the inflatable secondary habitats would be considerably different, so that

the astronauts could use the pre-packaged equipment to arrange each base module distinctly for specific tasks.

The primary purpose of the shelter base module on the surface of Mars – just like in the lunar test programme – would be to provide a place to rest, and one of the two full-fledged lavatories of the Mars base would be installed in the secondary habitat of the shelter base module.

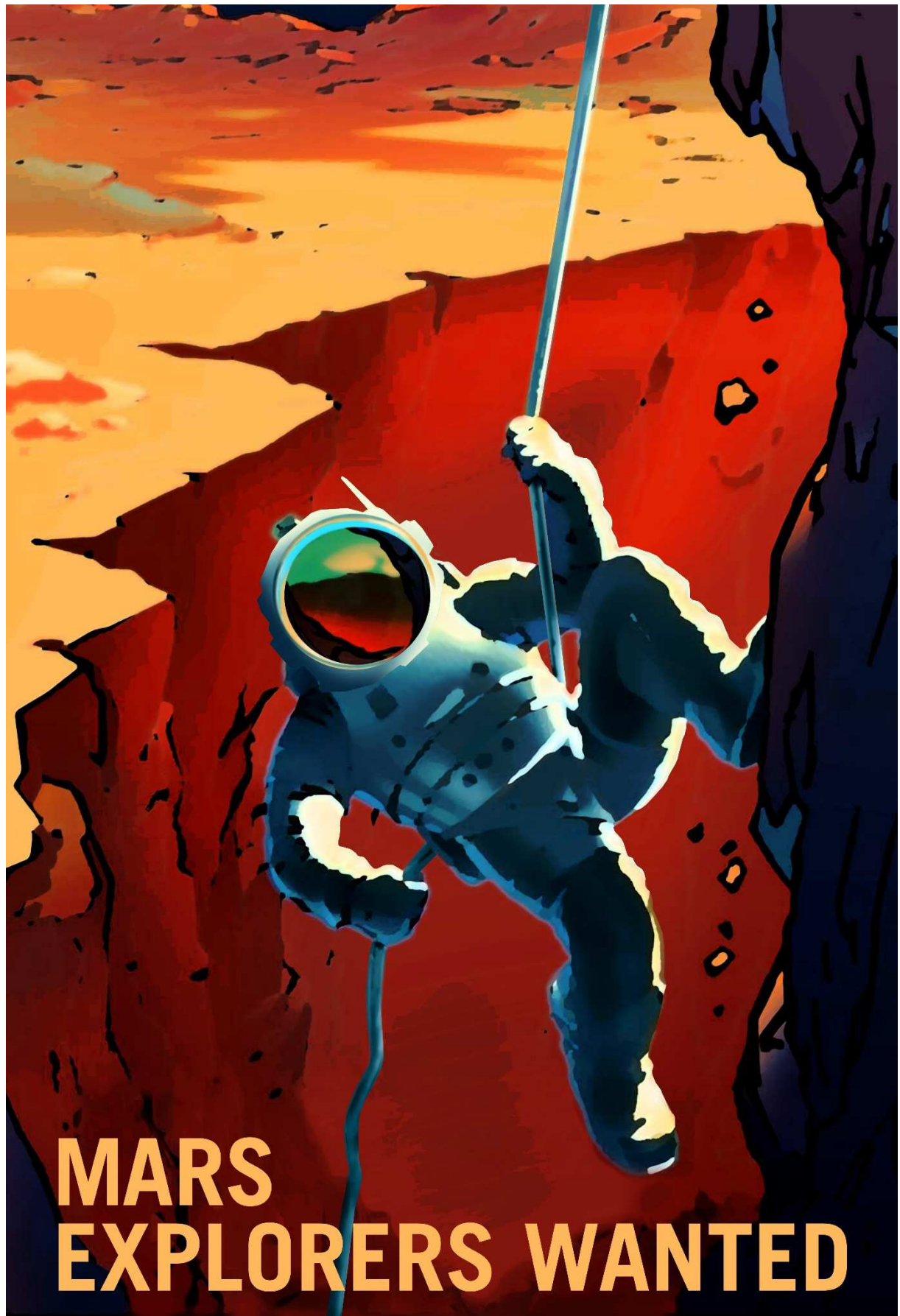
The other lavatory, which could only be used in an environment with gravity, would be in the secondary habitat of the recreational base module. This base module would be a common room for eating, sporting and entertainment, as well as for group activities to facilitate the physical and psychological regeneration of the astronauts.

The primary role of the communications base module would be to stay in contact with the ground mission control centre and with the gravity ring on geostationary orbit at all times, while this base module would also allow the astronauts to record high-resolution video messages for their families and to watch the videos they have received in private. The communications base module would also be a remote-control station where every spacecraft, space station module, lander, robotic dog and any other device of the Mars mission could be monitored and controlled remotely.



162. Mission Operations Control Room in the Apollo Mission Control Center at NASA's Johnson Space Center (Credit: NASA)

Since the communications base module would be equipped with screens, high-resolution cameras and a broadband data link with the ground mission control centre, the communications base module would also be an infirmary, where even minor surgeries could be performed.



163. Mars Explorers Wanted - NASA recruitment poster (Artist's Concept) (Credit: NASA)

Since the Mars mission could take up to two years, and the time spent on Mars with a toxic soil could be several months, the most important character of the Mars mission might be an astronaut with medical training and extensive medical experience. Since one Mars shuttle – beyond the two Mars shuttles that landed on the surface of Mars – would stay at the gravity ring as an emergency reserve, in case any of the two astronauts that stay on the gravity ring were to suffer an injury that requires urgent medical action, the injured astronaut would be able to use the reserve Mars shuttle with remote control to land directly next to the Mars base, where the astronaut with medical training could tend to the injured astronaut in the fully equipped infirmary of the communications base module, while the other astronauts could also assist in the surgery.

The workshop base module would include all the tools and instruments from wrenches to soldering irons to voltmeters for repairing and maintaining the landers, the landers' devices and other important equipment of the Mars mission, as well as those 3D printers, metalworking- and other machines that the astronauts might need to produce new tools and components in case the situation were to become so critical that not even electrical tapes could help.

The workshop base module itself would also be a drilling equipment, that is, once the Mars base has been established, the astronauts could use the workshop base module to drill several tens of metres into the Martian soil within the framework of scientific work to obtain samples from the surface of Mars. As rather deep drillings could be performed using the workshop base module, the astronauts could minimise the number of such EVAs and also reduce consequential radiation exposure, as the astronauts would stay in the pressurised secondary habitat of the workshop base module throughout the drillings.



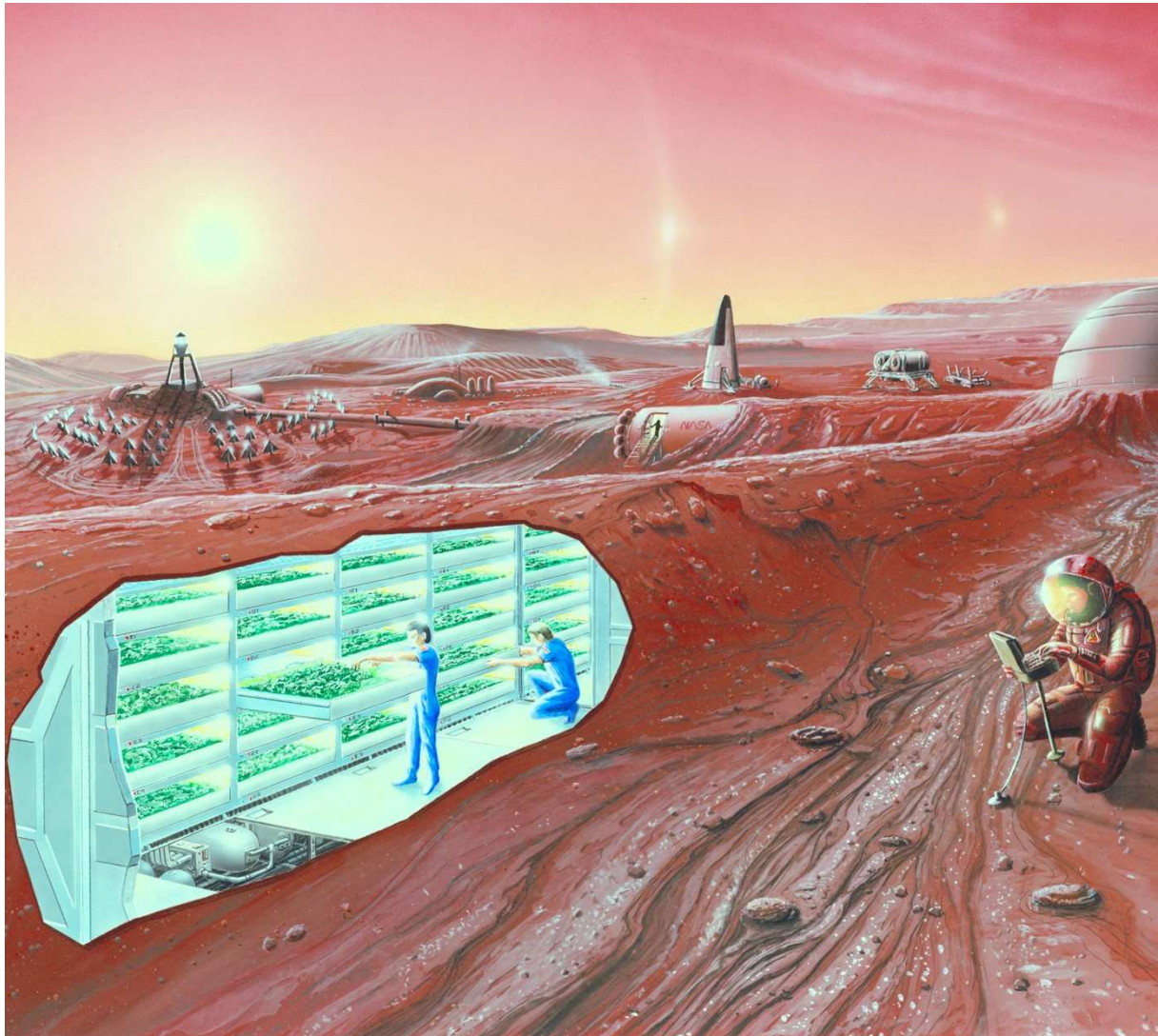
164. Astronauts study rocks on Mars (Artist's Concept) (Credit: NASA)

Since the workshop base module, similarly to the other landers, would also move using its ATHLETE robotic legs, in case the astronauts were to find a propitious sampling point far from the original location of the Mars base, then the entire Mars base, thanks to its limitless mobility and to the

constant power supply of the nuclear supply module, could be moved there nice and slowly, so that the workshop base module would be right over the planned location of drilling.

The scientific base module of the Mars base would be a smaller research station to be used as a meteorological station and as a laboratory at the same time, containing all the instruments and devices that might be needed to reveal the secrets of Mars. Most time of the months when the astronaut would be staying on the surface of Mars would be spent with research work in the scientific base module to obtain accurate data on the close proximity of the Mars base as soon as possible – e.g. on the chemical composition of the soil –, so that crop production experiments exploiting Martian soil could be started. These crop production experiments would be performed in the scientific base module instead of the aeroponic base module.

Namely, the aeroponic base module would specifically be intended to allow the astronauts to produce fresh and nutritious vegetables for themselves during the months of the mission on the surface of Mars in order to maintain their physical fitness and improve their well-being by eating healthy food.



165. Mars colony with an interior horticultural area (Artist's Concept) (Credit: NASA)

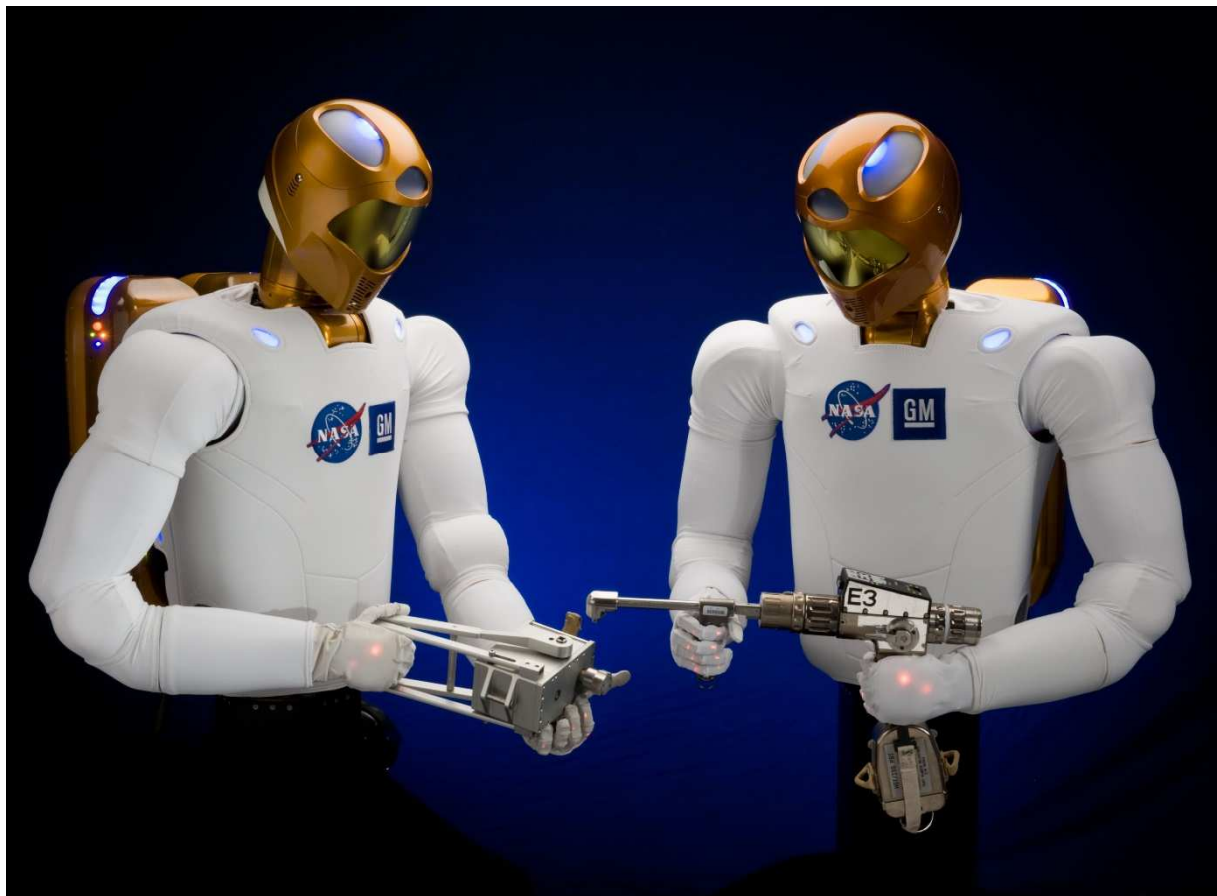


166. AI SpaceFactory 3D-Printed Mars Habitat (Artist's Concept) (Credit: AI SpaceFactory)

However, the aeroponic base module would also have a secondary role. The astronauts would also grow low-maintenance houseplants in this base module, and directly before the end of the Mars mission and finally leaving the Mars base, the astronauts would place houseplants in each base module, thus practically turning the entire Mars base into a conservatory. Perchlorate-free Martian soil enriched with organic manure and bacteria would be used for the permanent settling of these houseplants.

Since the nuclear supply module would keep on supplying the Mars base with power even after the astronauts have left the surface of Mars, the optimal internal temperature for crop production and the ideal light conditions for photosynthesis could be maintained for an unlimited period of time in the base modules, and since several tens of tonnes of LOX/LH2 rocket fuel – to be used as emergency reserve for the mission on the surface of Mars – would remain in the four propellant shuttles left behind at the Mars base, an abundant amount of water would also be available for the regular irrigation of the plants.

The plants would be maintained by a Robonaut humanoid robot – which would be part of the equipment of the Mars base – controlled remotely by the ground mission control centre. Unlike the robotic dogs, the Robonaut would be staying in the pressurised habitat of the Mars base as a kind-of robotic janitor to perform works that do not require extreme physical effort, and, as such, it would have a much simpler structure than the robotic dogs, with an extremely energy efficient operation as well.



167. Two Robonaut 2 humanoid robots (Credit: NASA)

Since the most important task of an upcoming mission on the surface of Mars would be to construct a 3D printed protective shield of Martian soil that provides sufficient protection against radiation for the landers of the Mars base, the astronauts could use the plants to create a much more liveable environment in the sterile habitat of the permanently located Mars base, while answers could also be found with regard to the usability of Martian soil for crop production.

5.4 The Way Back Home

Out of the eight propellant shuttles that landed on the surface of Mars, four would be selected to take off, two for one Mars shuttle, and two for the other Mars shuttle. These propellant shuttles would already be completely refuelled after the Mars base has been established and would be awaiting the take-off, however, Mars shuttles that are unable to cool their own cryogenic tanks would be refuelled directly before the take-off through their resource-distribution connectors. Two astronauts would be in each of the two Mars shuttles for the take-off – just like in the case of the landing –, but this time, the astronauts would be accompanied by rock samples of at least a hundred kilograms.

The preparations for the take-off would proceed simultaneously for both Mars shuttles in the manner already tried and tested in the lunar test programme, however, for safety reasons, the second Mars shuttle would only leave the surface of Mars after the first Mars shuttle has already reached the gravity ring on geostationary orbit.



168. Perseverance rover landing on the surface of Mars (Artist's Concept) (Credit: NASA)



169. Mars - JPL Visions of the Future poster (Artist's Concept) (Credit: NASA)

At the same time with the preparations for taking off from the surface of Mars, the two astronauts remaining on the gravity ring would also prepare for implementing the emergency protocols related to the take-off, stop the rotation of the gravity ring, and would completely refuel with LOX/LH2 rocket fuel both the technical service spacecraft and the third Mars shuttle that is still connected to the gravity ring. After refuelling, both spacecrafts would detach from the gravity ring with one astronaut aboard each spacecraft.

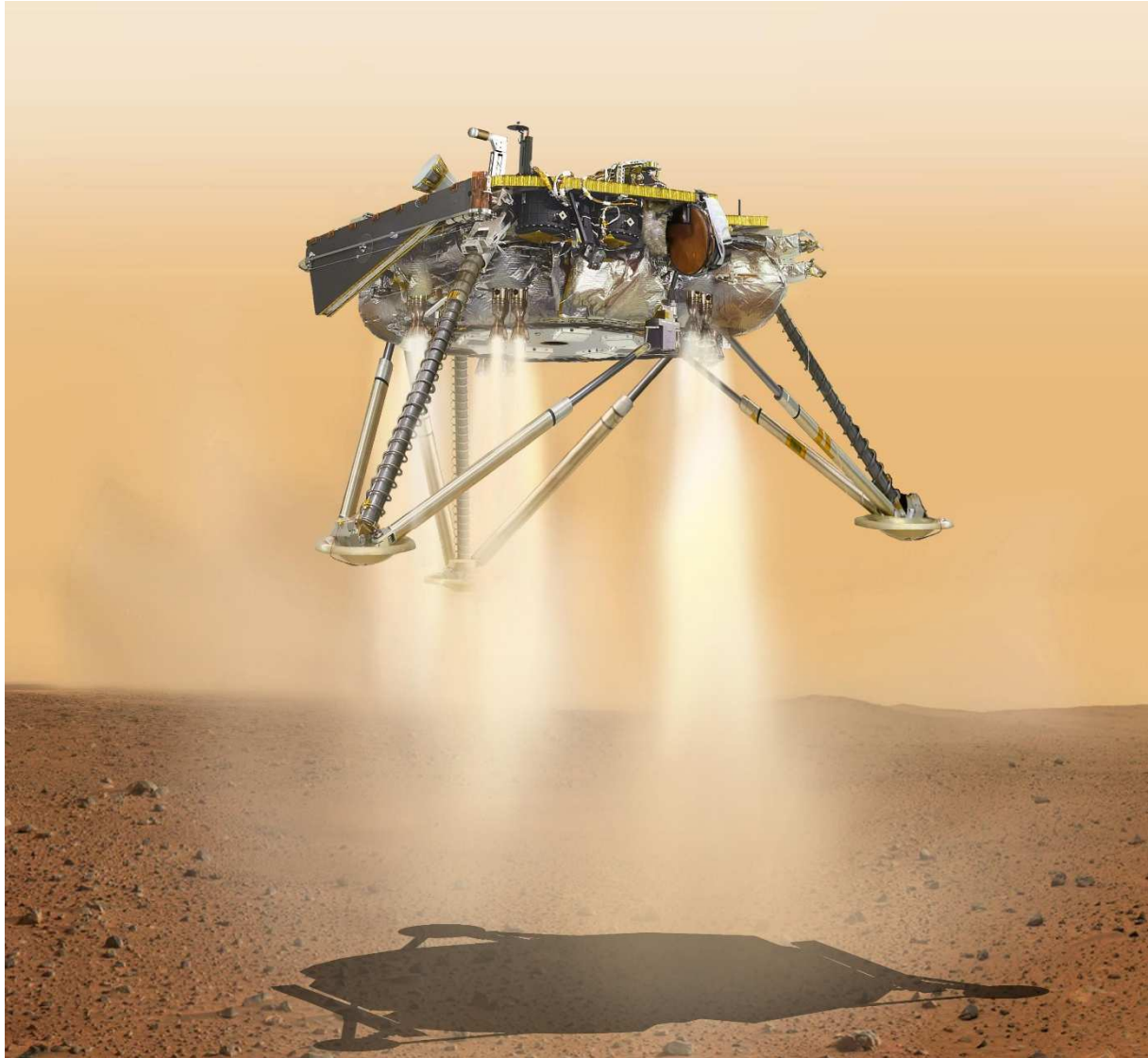
In case a malfunction or any other technical or control-related issue were to arise during the take-off of any Mars shuttle, and consequently the given Mars shuttle would only be able to reach low Mars orbit, the astronauts aboard would be able to detach the crew module from the Mars shuttle, leave the service module of the Mars shuttle and the connected propellant shuttles behind, and reach the gravity ring – on a higher Mars orbit – aboard the crew module by using its own LOX/LH2 rocket engines only, and then would be able to dock at the docking port of the life-supporting space station module of the gravity ring.



170. Rocky Mars surface (Credit: ESA)

Since the technical service spacecraft would also be on stand-by during the take-offs of the Mars shuttles, in case any Mars shuttle would only be able to reach low Mars orbit due to technical issues, the technical service spacecraft could be used to fetch the malfunctioning Mars shuttle, as the technical service spacecraft could use its Canadarm robotic arms to tow the Mars shuttle to the gravity ring on a higher Mars orbit.

In case a malfunction of the rocket engines or other essential components of a Mars shuttle would render it unable to reach low Mars orbit upon take-off, or a technical malfunction would create an explosive situation upon take-off, the astronauts would perform an emergency detachment with the crew module of the Mars shuttle from the service module of the Mars shuttle, and in case it seems even the crew module alone is unable to reach low Mars orbit, the astronauts would land again on the surface of Mars in the crew module of the Mars shuttle.



171. InSight lander about to land on the surface of Mars (Artist's Concept) (Credit: NASA)

In the latter case, if the astronauts survive the landing – which landing could actually be considered as an impact –, the life-supporting system of the severely damaged crew module would suffice for a limited period of time, and since the astronauts might have landed several hundred kilometres from the Mars base with this suborbital flight, the third – emergency reserve – Mars shuttle docking at the gravity ring could be used immediately to land as closely to the astronauts in distress as possible, move over to them using its ATHLETE robotic legs, and provide them with life-support until they transfer to the third Mars shuttle and the rescue operation is completed.

Since the third Mars shuttle would also be provided with a radioisotope thermoelectric generator, capable of producing sufficient power for the communications equipment of the Mars shuttle and sufficient heat to maintain an ideal temperature in the habitat of the crew module of the Mars shuttle, and since liquid oxygen remaining after the landing could provide the astronauts with oxygen for nearly an unlimited period of time, the three astronauts might feel tight and uncomfortable, but could safely wait in the crew module of the third Mars shuttle.



172. Surveyors Wanted - NASA recruitment poster (Artist's Concept) (Credit: NASA)

There would be several alternatives to pick up the third, emergency escape Mars shuttle. In case such accident were to happen to the first Mars shuttle to take off, the other two astronauts still waiting at the Mars base would drive to the location of landing with one Mars exploration vehicle and with the nuclear supply module – connected to the vehicle through a flexible charging cable –, where they would connect the Mars shuttle to the nuclear supply module through one of its resource-distribution connectors, and then all these three landers could use their ATHLETE robotic legs to go back to the Mars base nice and slowly, while being provided with constant and abundant energy.

Another solution to pick up the third Mars shuttle is to land propellant shuttles near the third Mars shuttle. In case an accident were to happen to the first Mars shuttle to take off, the propellant shuttles that were refuelled completely for the other Mars shuttle could perform a brief suborbital flight of a few minutes to reach the astronauts who have suffered an accident, and in case an accident were to happen to the second Mars shuttle to take off, the reusable propellant shuttles, after refuelling at the gravity ring, would be controlled remotely to descend back into the Martian atmosphere and land near the accident.



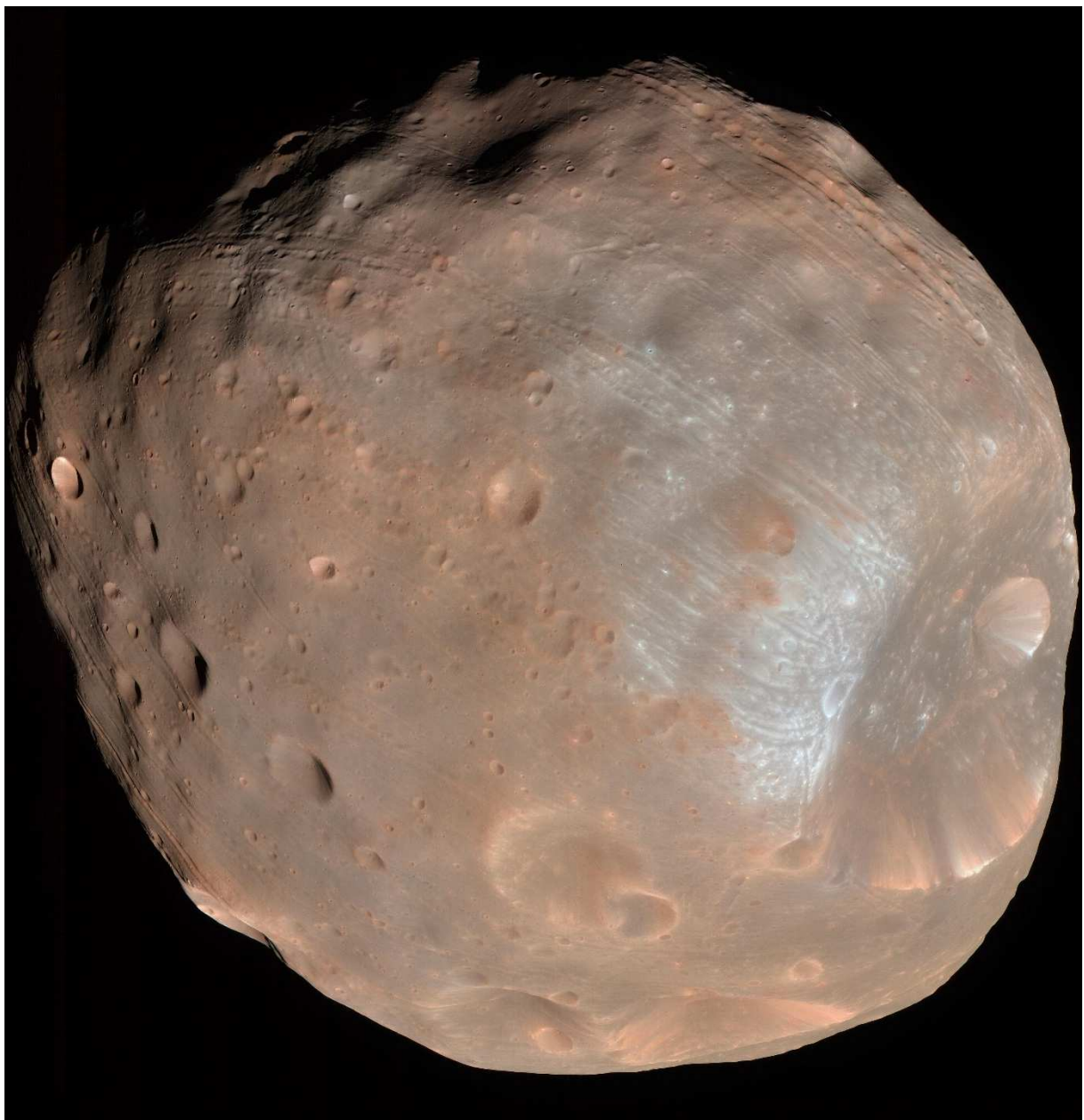
173. Bonneville impact crater on Mars (Credit: NASA)

The amount of liquid hydrogen and liquid oxygen rocket fuels to be sent down with the eight propellant shuttles to the surface of Mars when establishing the Mars base within the Phoenix Program would be enough abundantly for the take-off of three Mars shuttles, and, unlike the other landers, the propellant shuttles would also be equipped with heat shields of ceramic tiles, allowing them to be used any number of times, and the cryogenic tanks making the structure of the gravity ring would store a tremendous amount of LOX/LH2 rocket fuel for emergencies and return journeys,

and consequently, even extra LOX/LH2 rocket fuel could be sent down to the surface of Mars using the propellant shuttles.

As the Mars shuttles would only transport two astronauts by default despite being designed for four astronauts, as two propellant shuttles would be enough for the take-off of each Mars shuttle while being provided with four fixing points, and as much more than necessary rocket fuel would be sent down to the Mars base with the propellant shuttles, the astronauts would be able to respond to a sheer number of emergencies in a flexible manner, ensuring their safe return to the gravity ring.

Once every astronaut of the mission on the surface of Mars have reached the gravity ring, the astronauts would prepare to return to the Earth. However, before they would readjust the centre of gravity of the gravity ring and restart its rotation, the two astronauts who didn't take part in the mission on the surface of Mars would visit both moons of Mars to collect rock samples.



174. Phobos, one of the two moons of Mars (Credit: NASA)

Both Phobos and Deimos have a negligible gravity, which would make landing on them with a Mars shuttle without its secondary heat shields and collecting samples on spacewalks taken on the surface of the moons utterly complicated, because there would be a constant risk of falling off the surface. For this reason, the astronauts would approach both moons with the technical service spacecraft, and rock samples would also be collected with the help of the Canadarm robotic arms of the technical service spacecraft.

Once the rotation of the gravity ring has been restarted, the astronauts would leave geostationary orbit and return home, to low Earth orbit, which provides a relative protection. While the journey in deep space towards Mars would be taken on an energy efficient course to spare liquid hydrogen and liquid oxygen rocket fuels for emergencies in deep space or on the surface of Mars, the way back home could consume all the rocket fuel reserves available to reduce the time of returning home to a fragment of the nine-months-journey towards Mars.



175. NASA astronaut on the surface of Mars (Artist's Concept) (Credit: NASA)

Epilogue: Fast-Forwarding to the Future

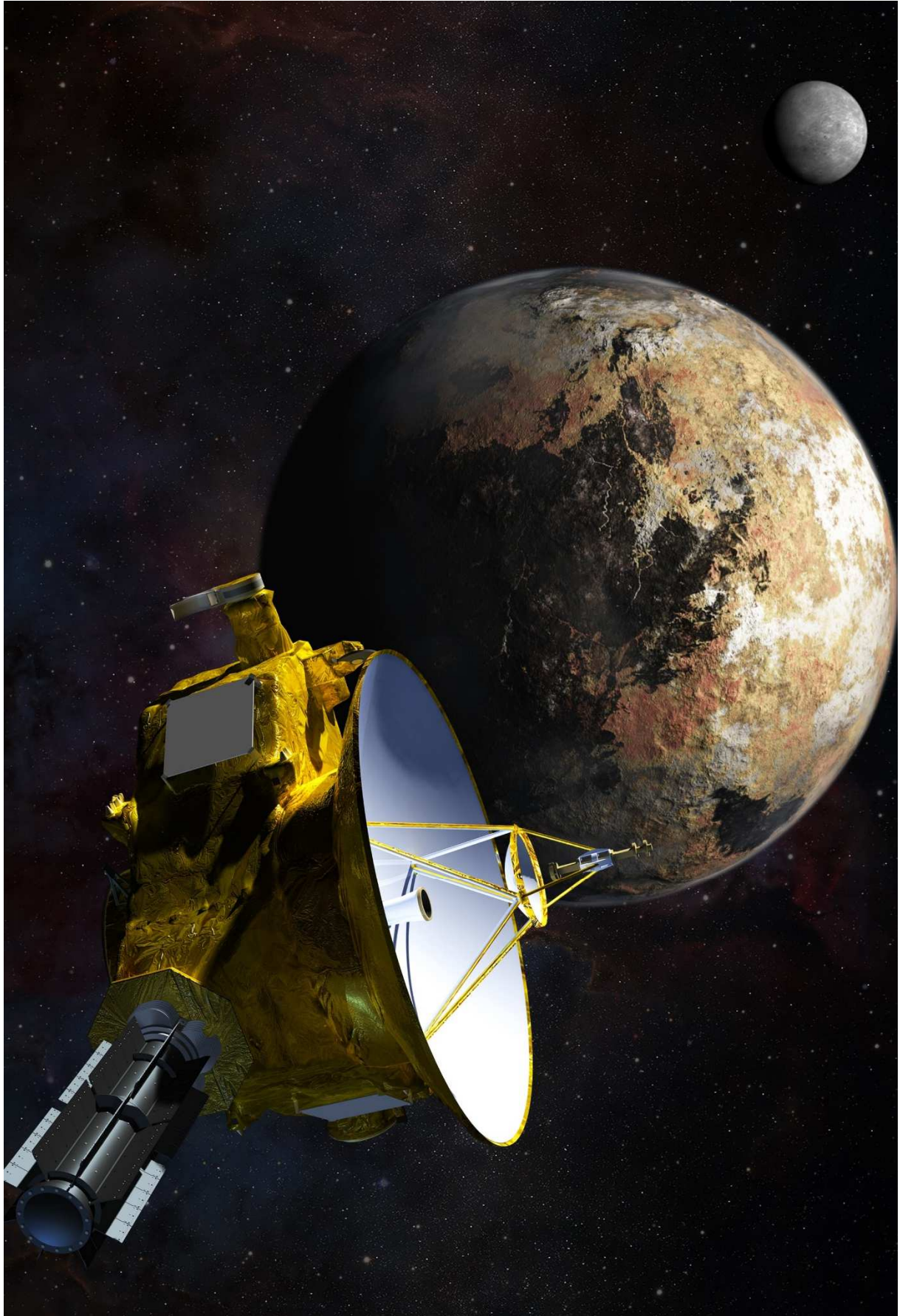
There are basically two conceivable mission profiles for conquering Mars. The simpler one is a flag mission, where the most important goal is to broadcast the astronauts arriving on the surface and planting a flag, symbolically demonstrating the conquest of a new planet. This would merely require to stuff some expendable astronauts into a spacecraft with neither sufficient radiation protection nor artificial gravity, dispatch them to the surface of Mars and hope that no problems arise on this long mission. The other mission profile, however, would be a much more complex scientific mission, where stepping on the surface of Mars would only be another tiny step to unveil the secrets of our Solar System and to kick off the expansion of humankind towards space.

I've aspired for the latter mission profile in this document, and while Phoenix Program is associated with conquering Mars, I do believe that in case this program turns out to be feasible and successful, the next huge step of humankind would not be to establish a permanent Mars colony.



176. Wonders in the Antarctic Sea and Sky (Credit: NASA)

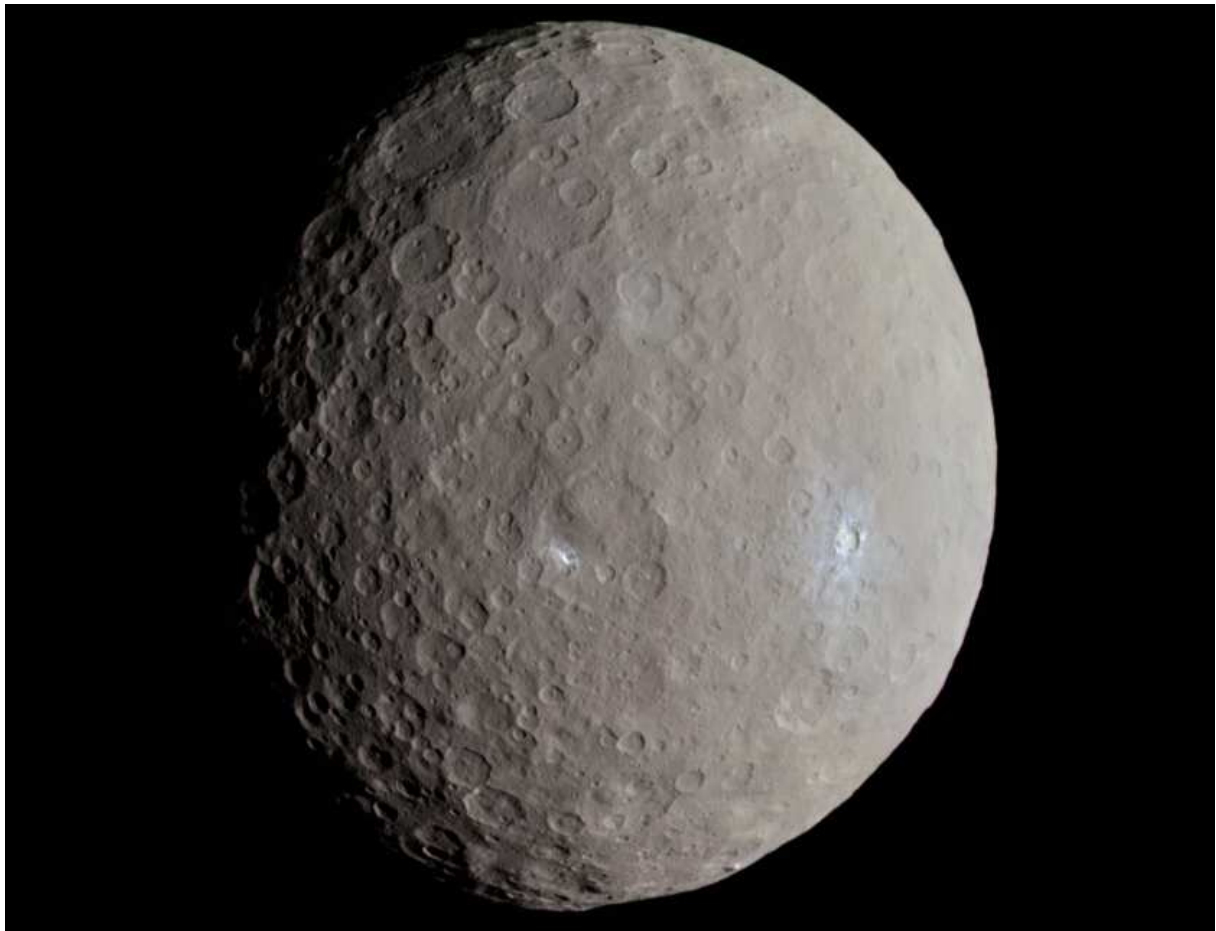
Since Mars is a cold and toxic desert, and as no metropolises are built on Antarctica either due to the poor level of stimulation, Mars, as a planet lacking resources, is not a credible alternative to the life on Earth. Moreover, even if there would be some people who are willing to live a precarious life on Mars, in an underground bunker-like colony, completely at the mercy of the regular replenishments sent from the Earth, the financial resources would always be missing to implement this solution.



177. *New Horizons* spacecraft as it approaches *Pluto* and its largest moon, *Charon* (Artist's Concept) (Credit: NASA)

Namely, the primary source of financing future manned space exploration programs would be asteroid mining, that is, the production of rare earth elements from helium-3 to platinum to other valuable materials and sending them down to the Earth, the execution of which would primarily require a rotating space station with artificial gravity. The gravity ring to be constructed within the framework of Phoenix Program would be suitable for this purpose, allowing us to extract valuable metals from near-Earth asteroids.

The so-escalating technological development and the considerable financial resources attracted to space exploration of scientific purposes through space industry could make it possible to take another huge step, that is, to establish a permanent space station at dwarf planet Ceres in the asteroid belt between Mars and Jupiter.

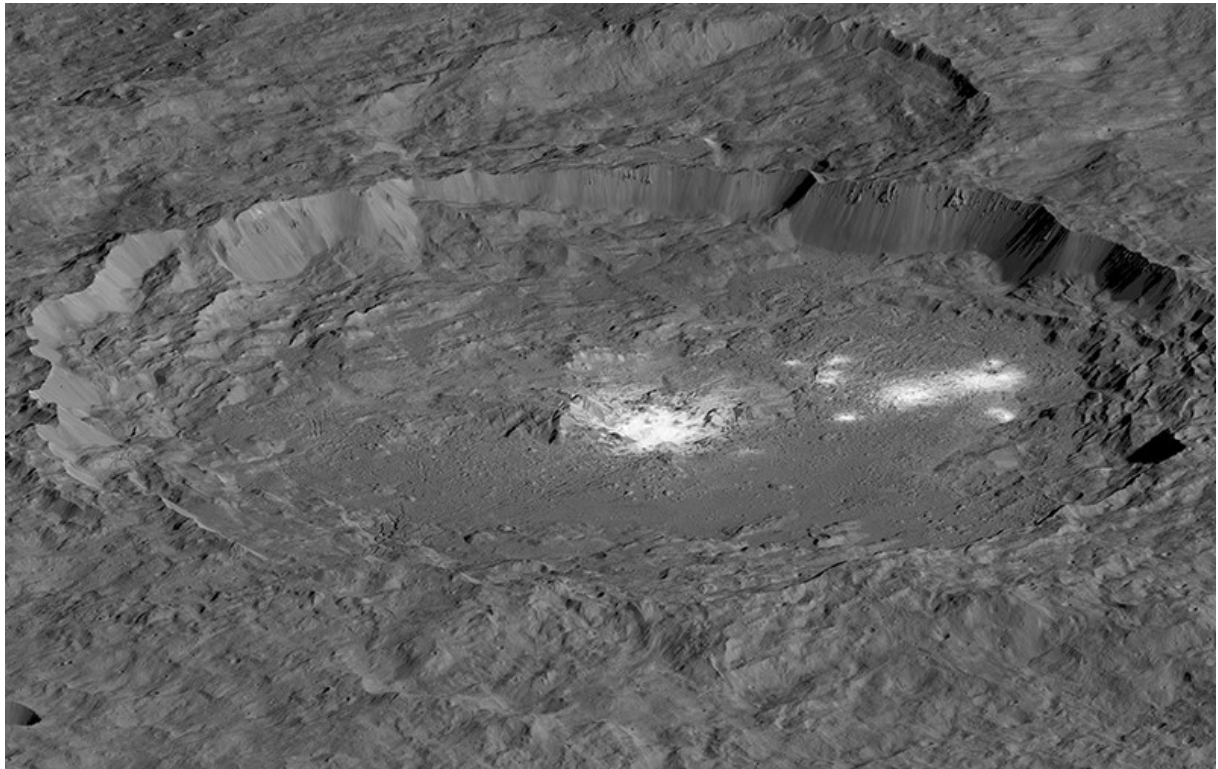


178. Dwarf planet Ceres (Credit: NASA)

In case the saline water under the surface in the Occator crater of dwarf planet Ceres is in liquid state, the water resources of Ceres could be extracted easily by drilling the crater, as no nuclear power plants would be needed for constant heat production to melt the frozen subsurface water, and the extracted water, thanks to the negligible gravity of Ceres, could be sent easily to a space station orbiting the dwarf planet. Since Ceres would this way become an unlimited and easily accessible source of water, the diameter of the habitat ring of the space station orbiting Ceres could reach one kilometre, the slow rotation of which could simulate the gravity of the Earth without constant sensory disorders arising due to Coriolis force hindering the everyday lives of the astronauts.

The habitat ring of this deep-space station of extreme dimensions could be established by interconnecting inflatable space station modules with a diameter of fifty metre each. There would be a few metres wide gangways in the middle of the inflatable space station modules; these gangways would be the backbone of the habitat ring of the space station, and would form a completely wraparound, pressurised and thermally insulated habitat.

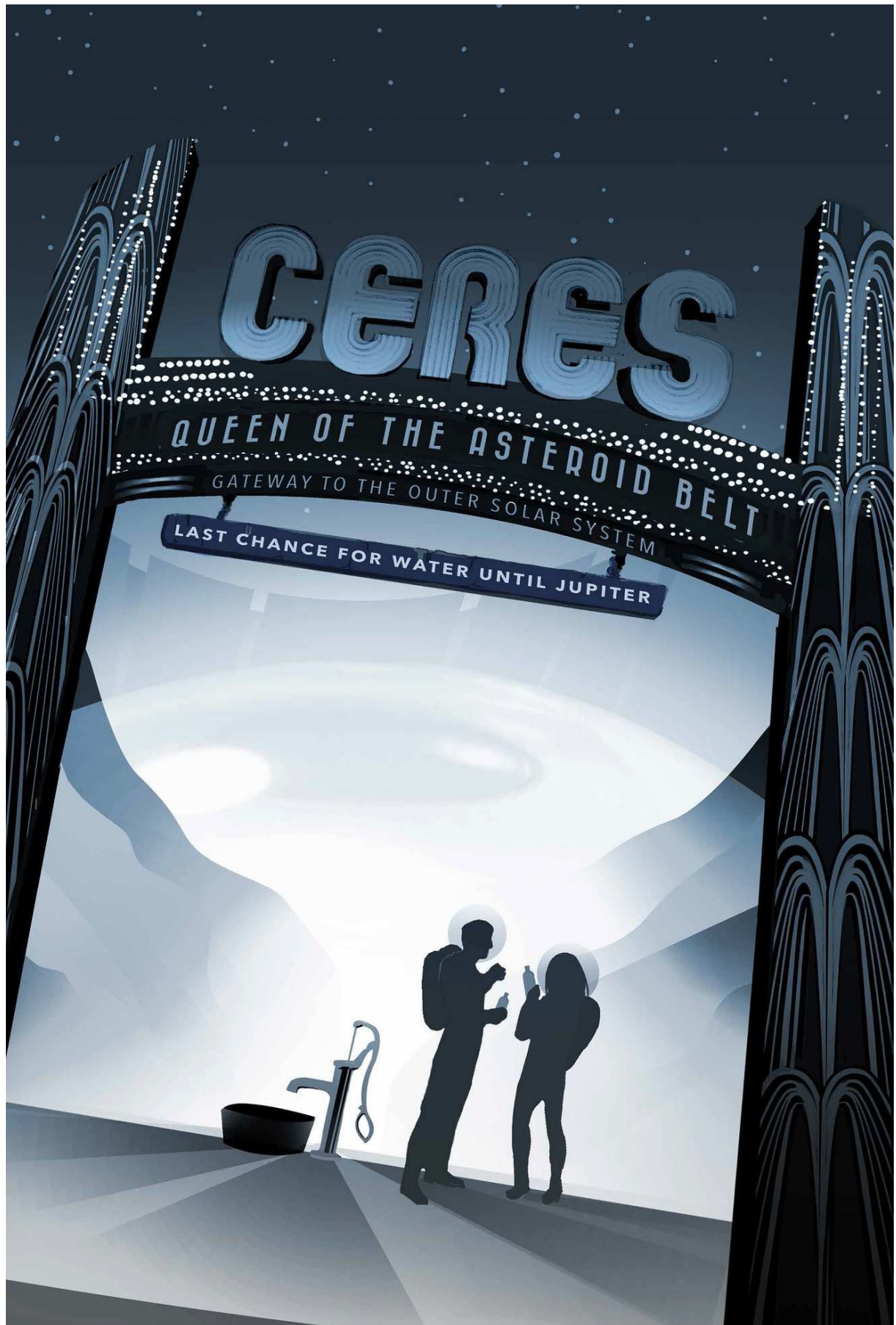
The space between the outer casing and the pressurised inner gangways of the inflatable space station modules could be filled with saline water from dwarf planet Ceres, the transportation of which, thanks to the minimum gravity of Ceres, could be solved easily by using shuttles or a space elevator.



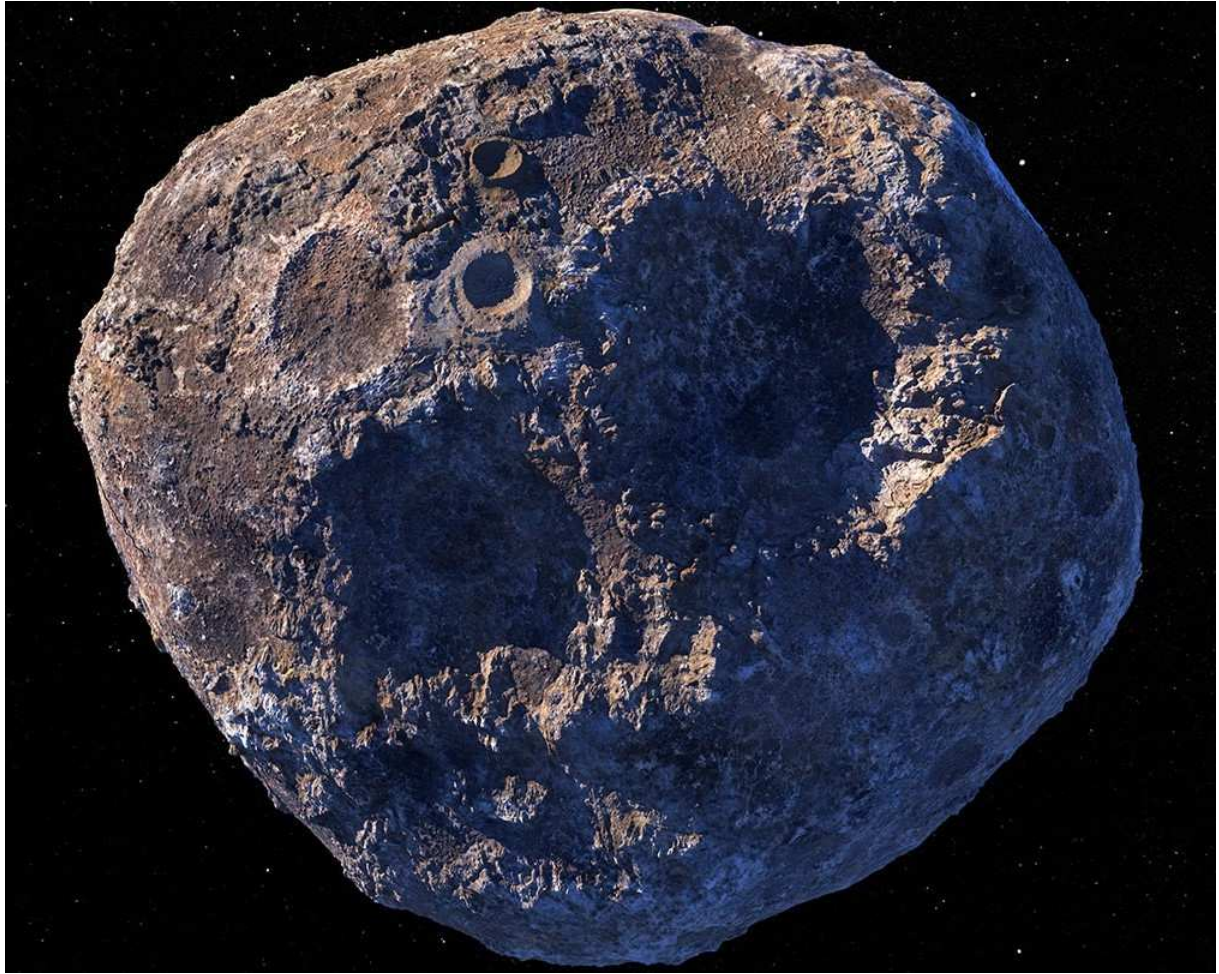
179. Occator crater on dwarf planet Ceres (Artist's Concept) (Credit: NASA)

The freezing of the saline water stored in the inflatable space station modules could form a solid structure, allowing anything to be placed freely in this structure by simply carving the required cavity in the ice. For example, if a new room is needed for sleeping, the ice should only be carved in the necessary dimensions near one of the pressure-tight sliding doors – which could be found in every inner gangway –, the sleeping room module with its originally folded casing should be placed in the carved cavity, connected the module to the pressure-tight door to inflate it, and then simply should be furnished at the astronaut's discretion.

This permanent space station to be established near dwarf planet Ceres, thanks to its unlimited water supply, could be designed to be self-sufficient in many aspects and to have fairly large storage capacities to become home for dozens or even hundreds of astronauts for several years. Moreover, since water is an ideal radiation-absorbing material, this rotating space station would be protected against both cosmic ray and solar flares.



180. Ceres - JPL Visions of the Future poster (Artist's Concept) (Credit: NASA)



181. Asteroid 16 Psyche (Artist's Concept) (Credit: NASA)

With the help of unlimited water resources and of the inexhaustible liquid hydrogen and liquid oxygen rocket fuel replenishments, countless robotic missions could be launched from moon Europa of Jupiter to moon Titan of Saturn to every other important part of our Solar System, while the space station itself could primarily operate as an asteroid mining centre, because, similarly to the gravity ring of Phoenix Program, this space station would also be a deep-space spacecraft allowing us to visit metallic asteroids in the asteroid belt, such as Psyche.

However, regardless of the dreams and opportunities to shape the future of manned space exploration, one thing is for sure.

There are no limits.



182. *We Need You* - NASA recruitment poster (Artist's Concept) (Credit: NASA)